Direct detection and gamma-ray signatures of a light scalar WIMP

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Chiara Arina

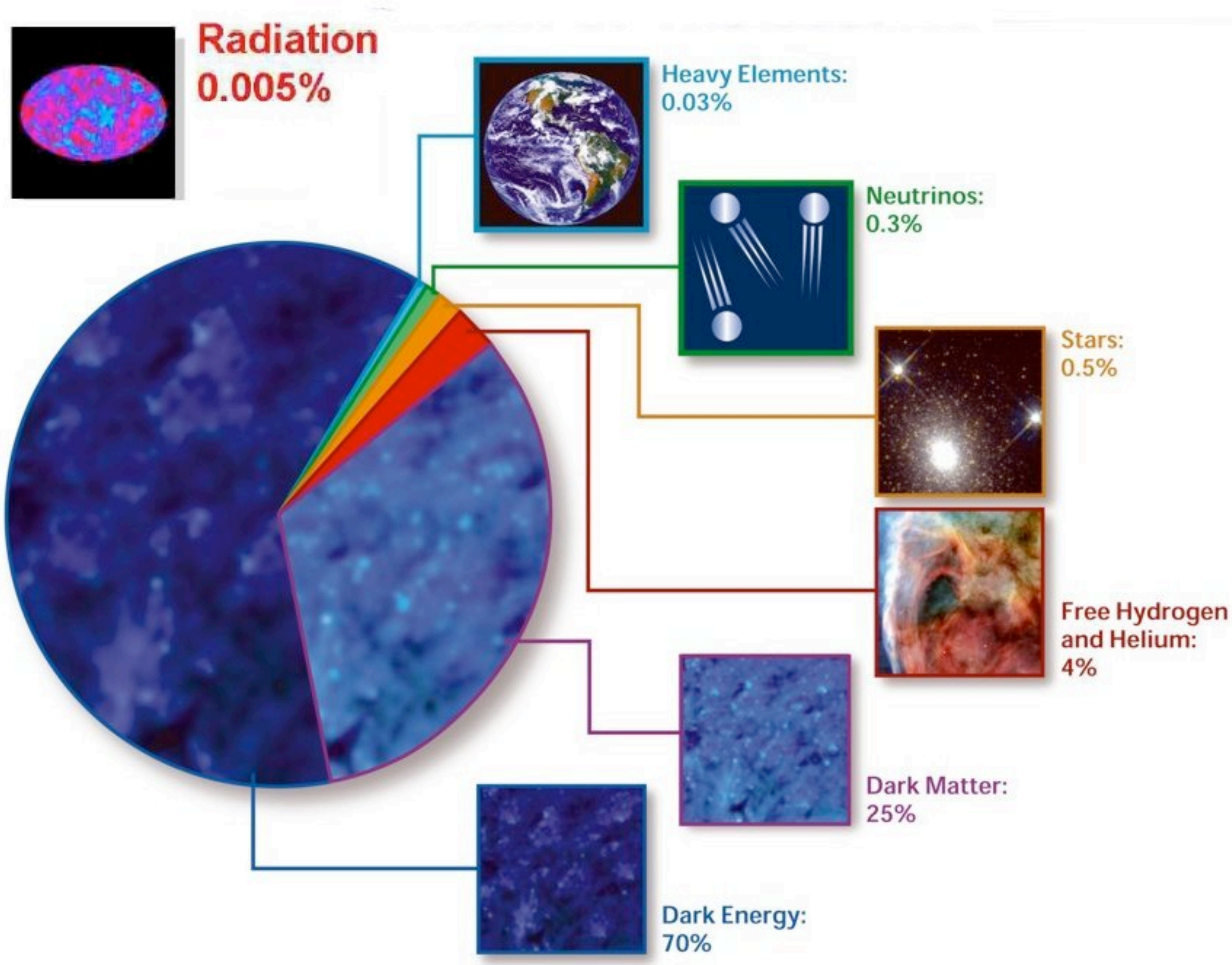
The Dark Universe

$\Omega_{\rm TOT}$
CMB temperature anisotropies

Ω_Λ
Luminosity distance of high-redshift SNIa

$\Omega_{\rm M}$
Clustered mass abundance

Ω_b
Clustered mass abundance and Primordial Nucleosynthesis



$\Omega_{\rm TOT}$	1.0052 +- 0.0064	$\Omega_{\rm M}h^2$	0.1349 +- 0.0036
Ω_Λ	0.728 +- 0.0035	$\Omega_{\rm DM}h^2$	0.1123 +- 0.0035
$\Omega_{\rm M}$	0.227 +- 0.014	$\Omega_b h^2$	0.02260 +- 0.00059
Ω_b	0.0456 +- 0.0016		
h_0	0.704 +- 0.025		

E.Komatsu et al., arXiv: 1001.4538
N.Jarosik et al., arXiv: 1001.4744
D.Larson et al., arXiv: 1001.4635

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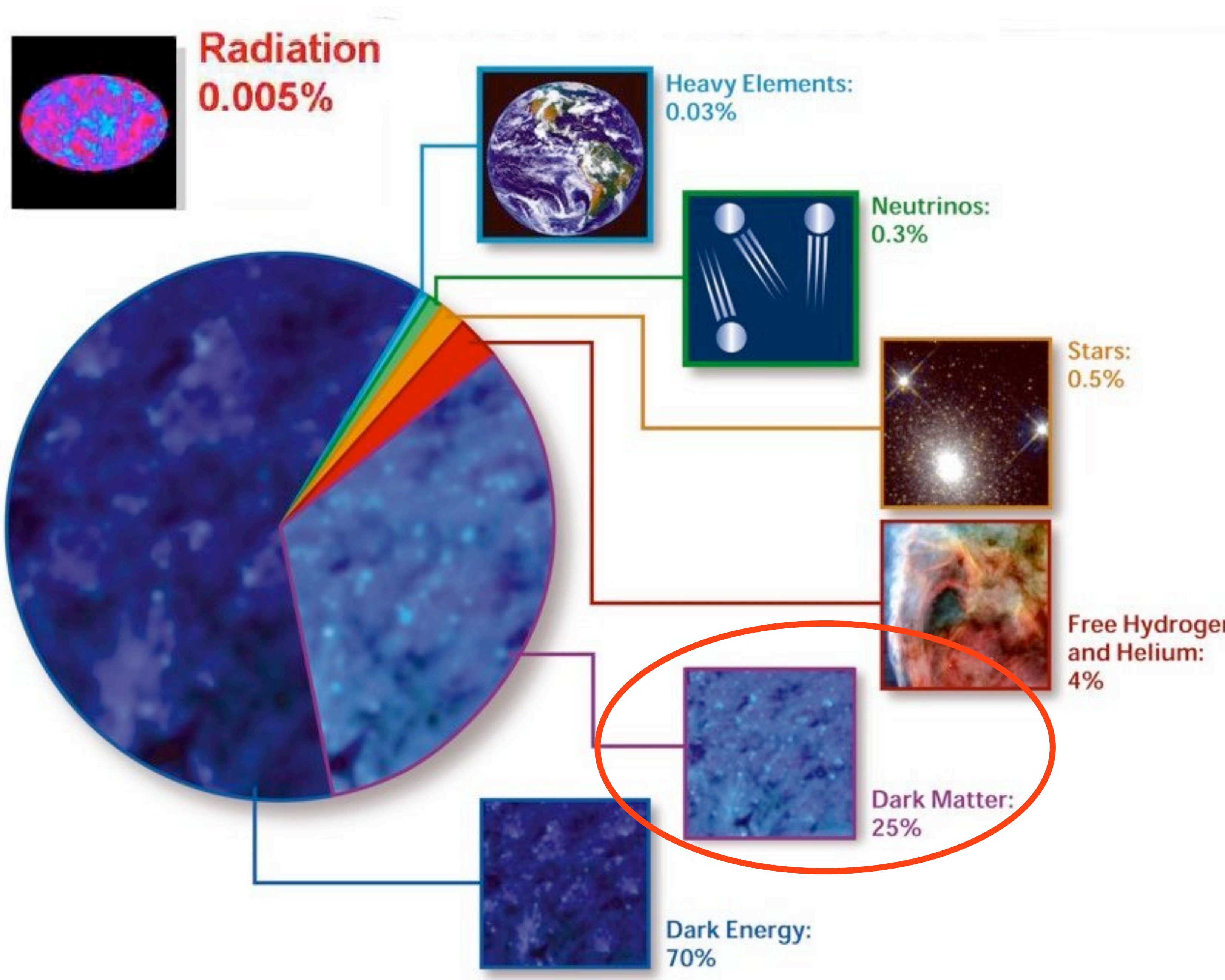

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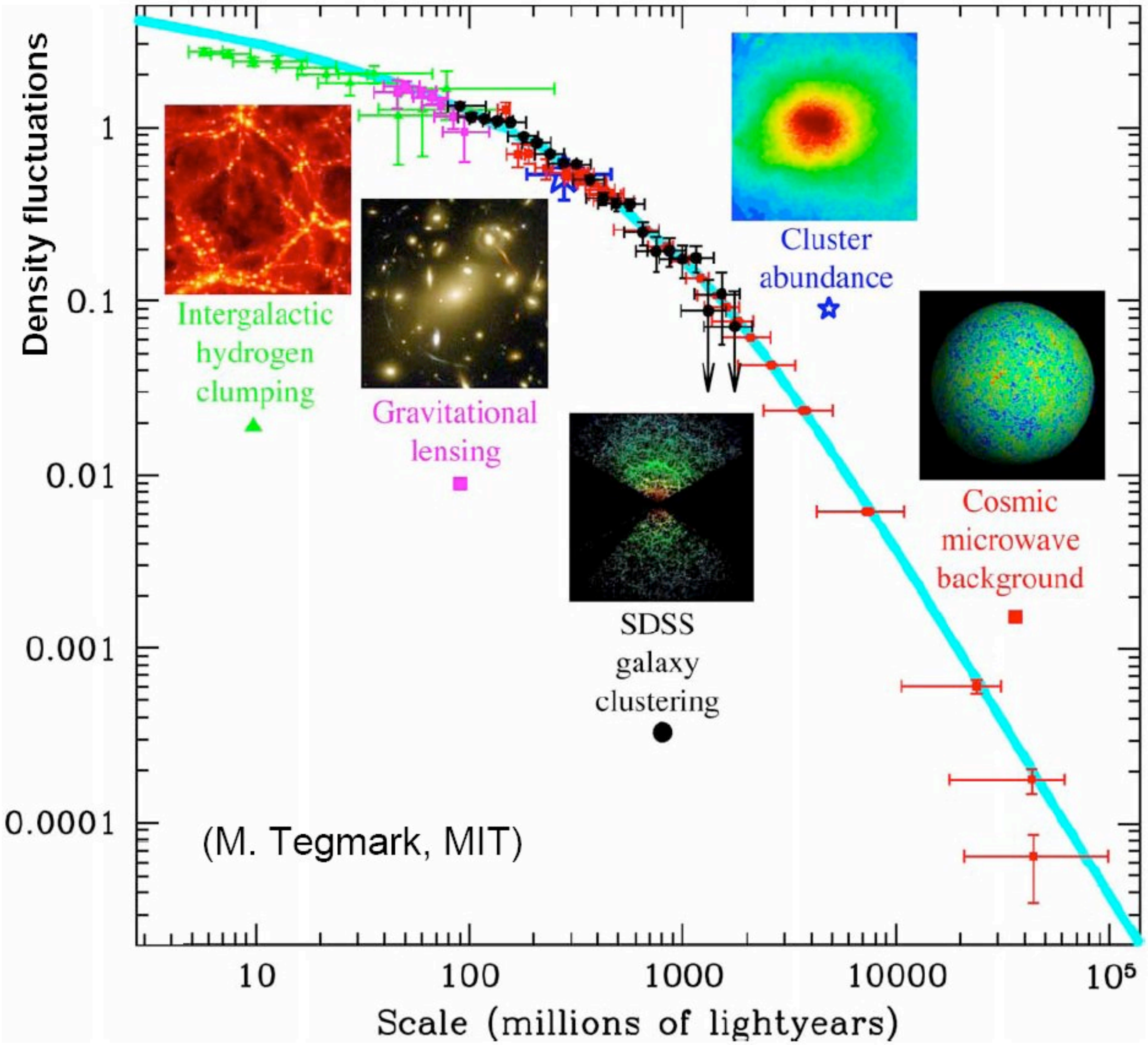
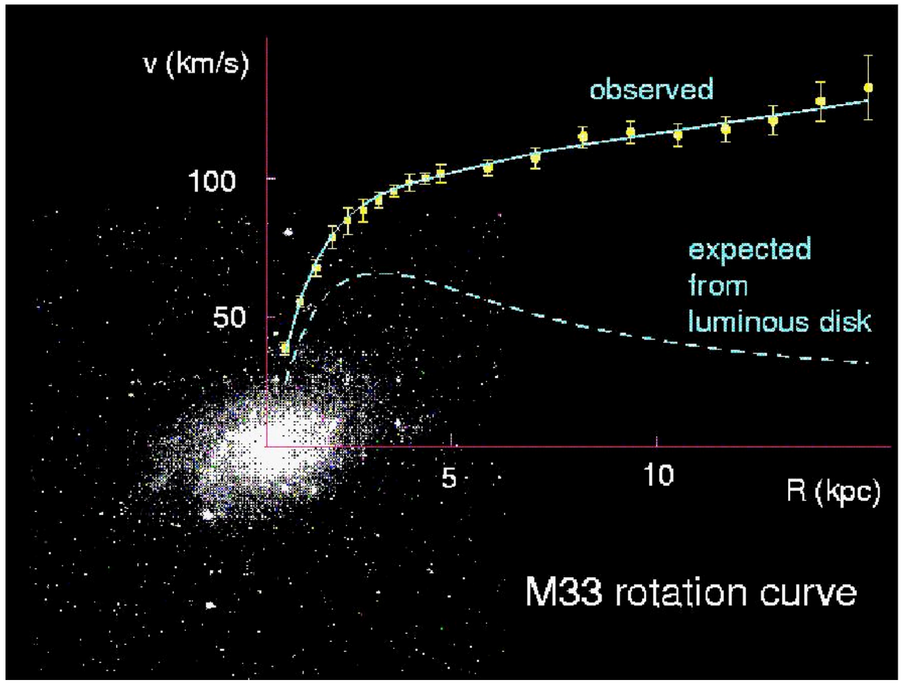


Evidences at all scales

(gravitational)

- Dynamics of galaxy clusters
- Weak lensing
- Structure formation from primordial density fluctuations
- Rotational curves of galaxies



Non baryonic Dark Matter (DM)

A candidate should fulfill:

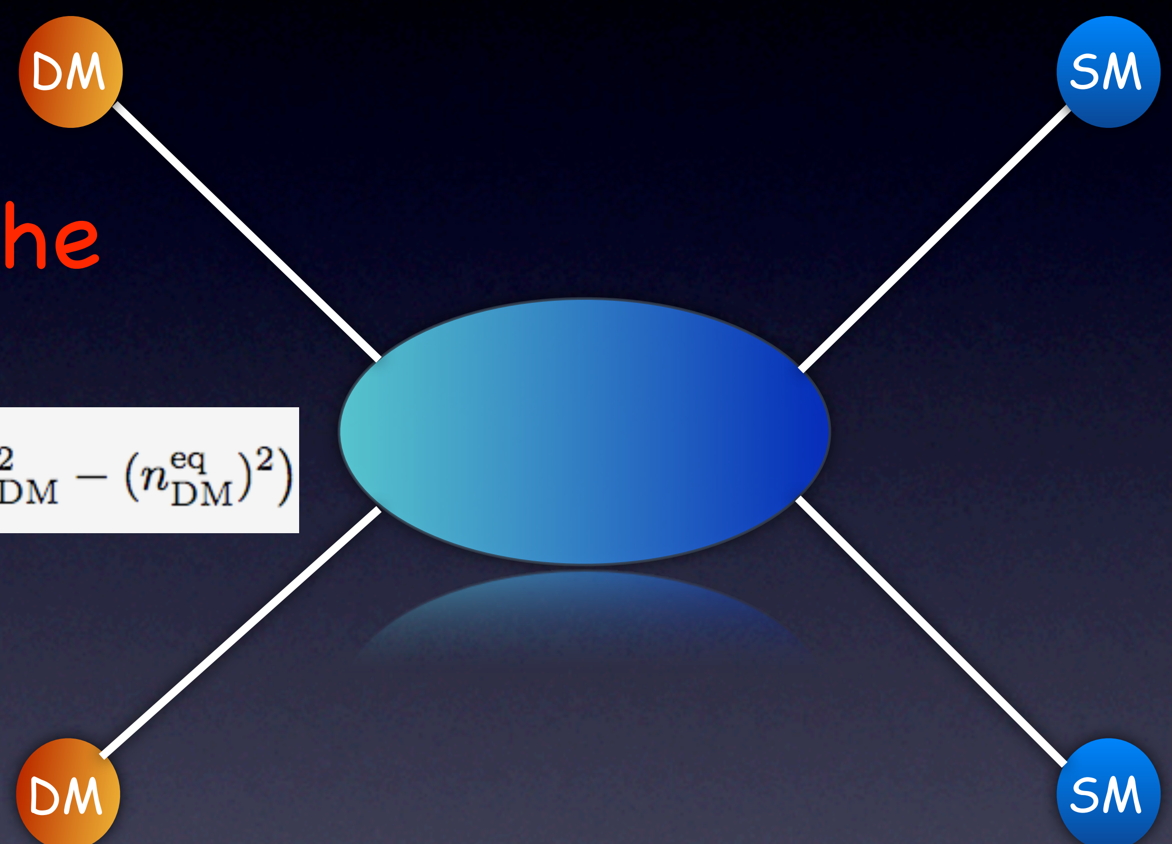
- Neutral, stable or late decaying
- Weakly interacting massive particle WIMP
- Thermal or non-thermal production
- Distributed to form an halo (clumps)

New physics beyond the Standard Model (SM)

Dark Matter Relic Abundance and Detection

Freeze out in the early Universe

$$\frac{d\,n_{\rm DM}}{dt} + 3n_{\rm DM}H(t) = -\langle\sigma v\rangle_{\rm ann}\left(n_{\rm DM}^2 - (n_{\rm DM}^{\rm eq})^2\right)$$



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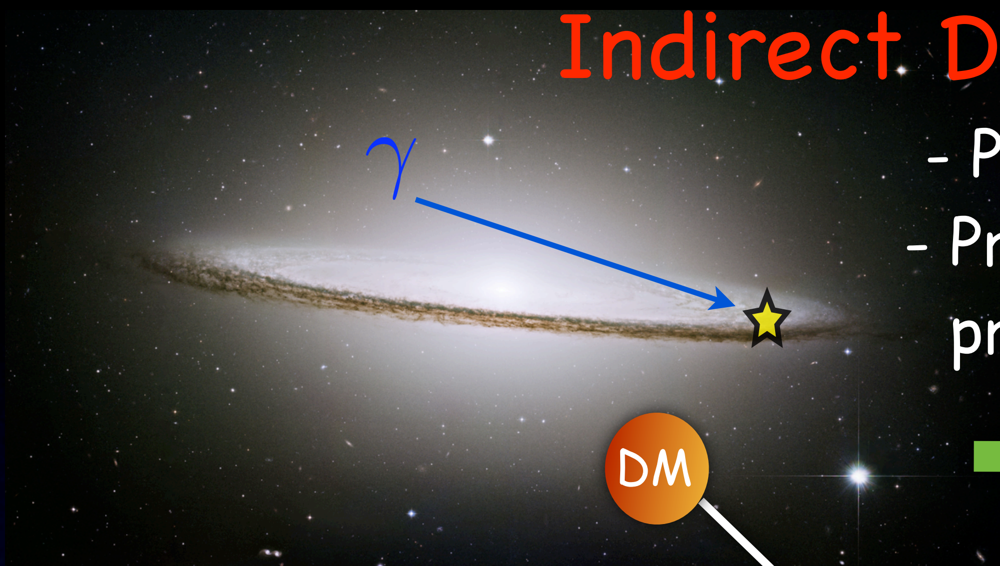
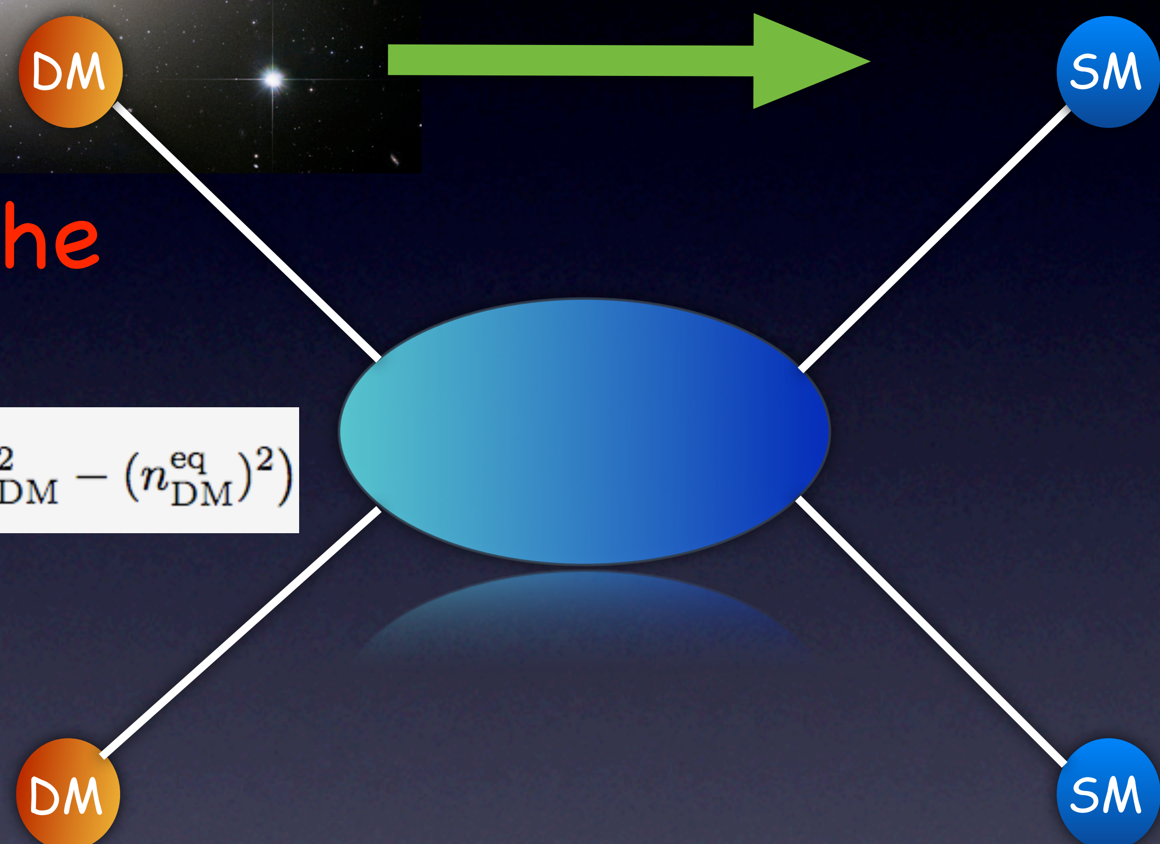


Indirect Detection (ID)

- Produced anti-matter that diffuse in the halo
- Produced photons and neutrinos (straight propagation from the source)



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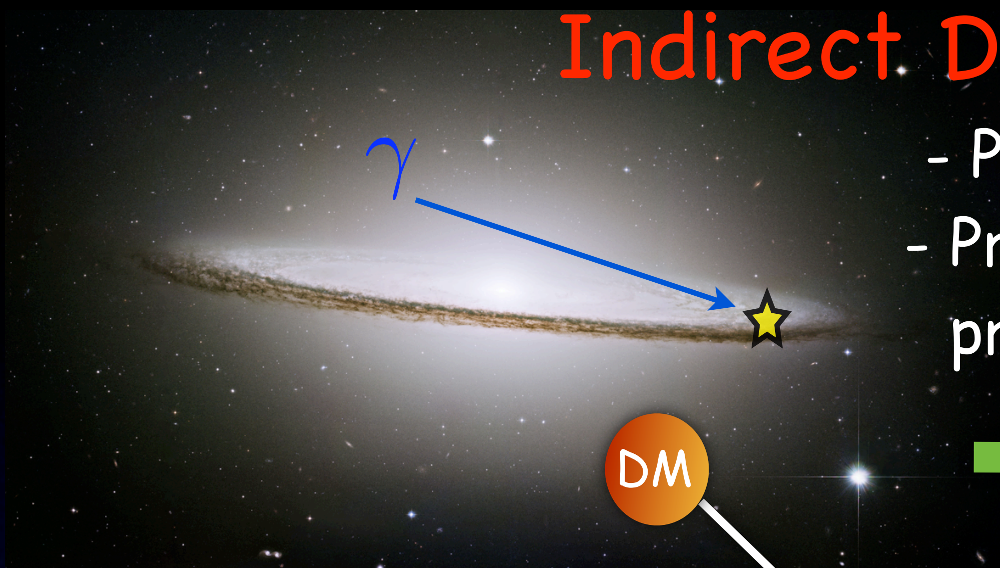

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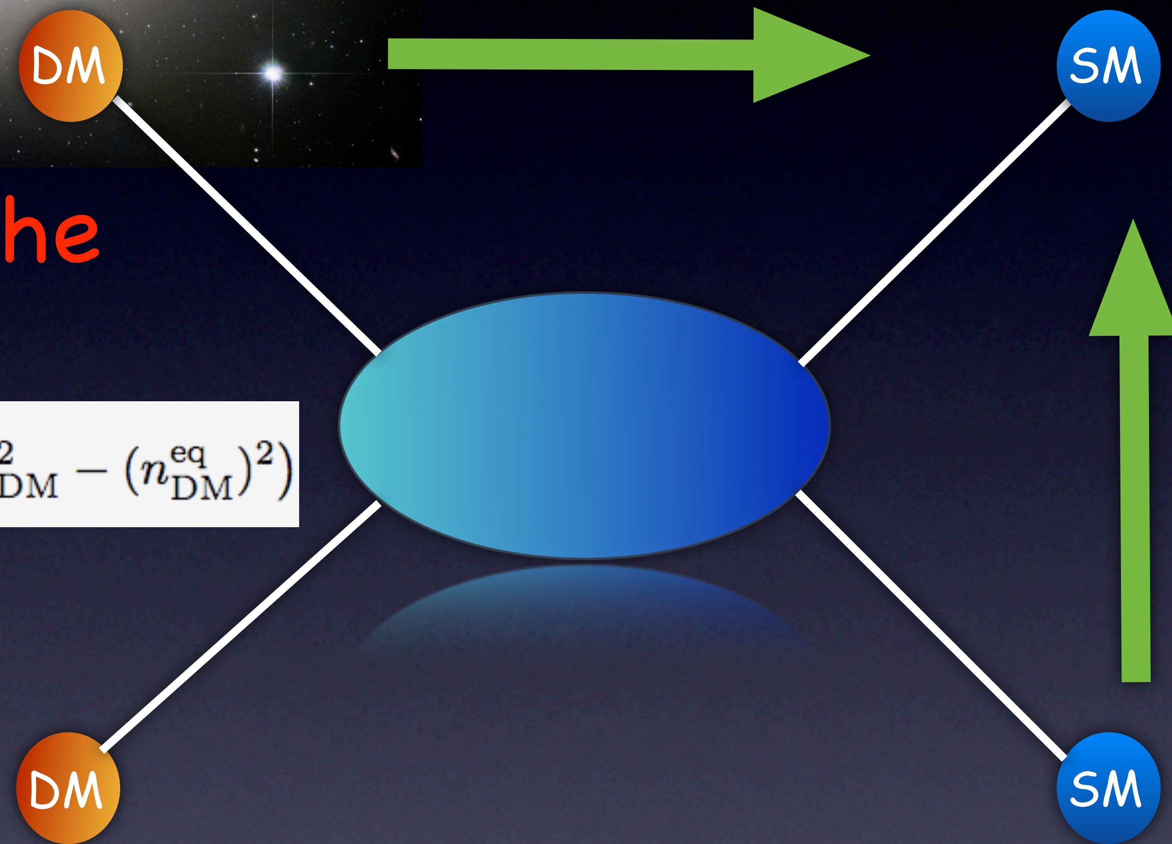

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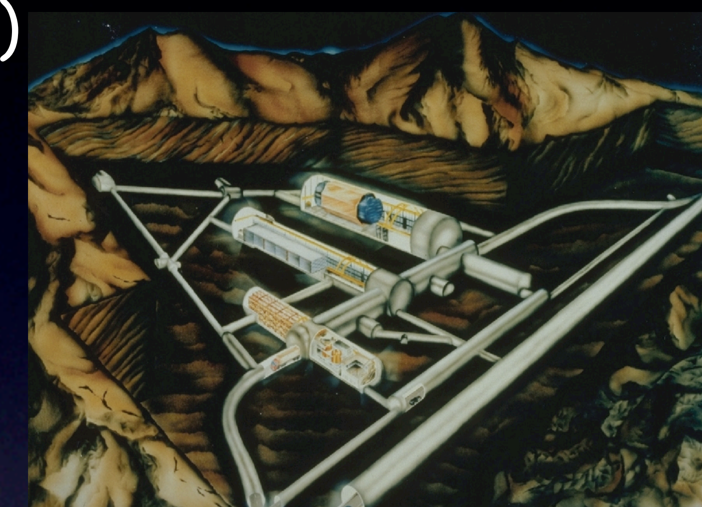
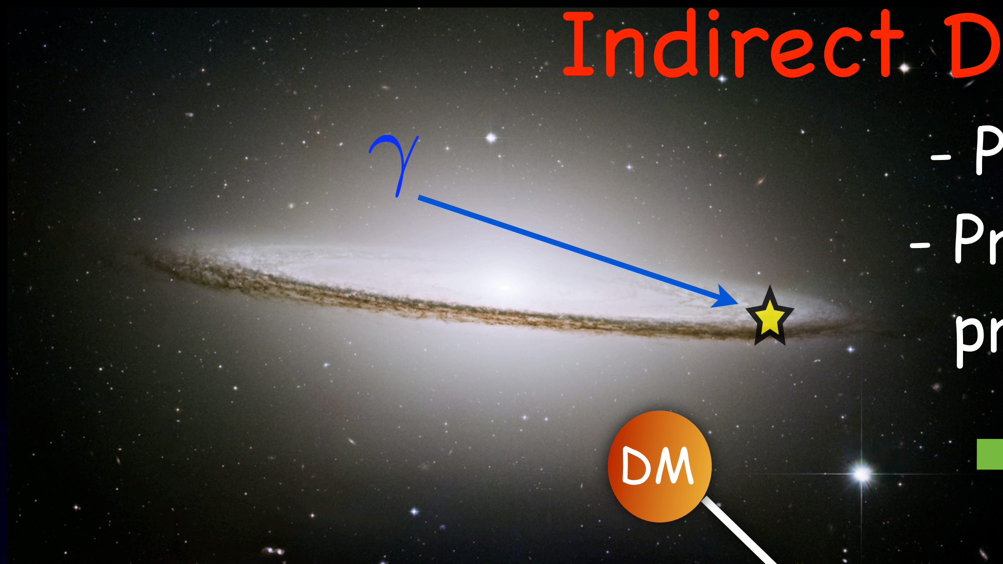


Direct Detection (DD)

Scattering off nuclei in underground detectors

Dark Matter Relic Abundance and Detection

Indirect Detection (ID)



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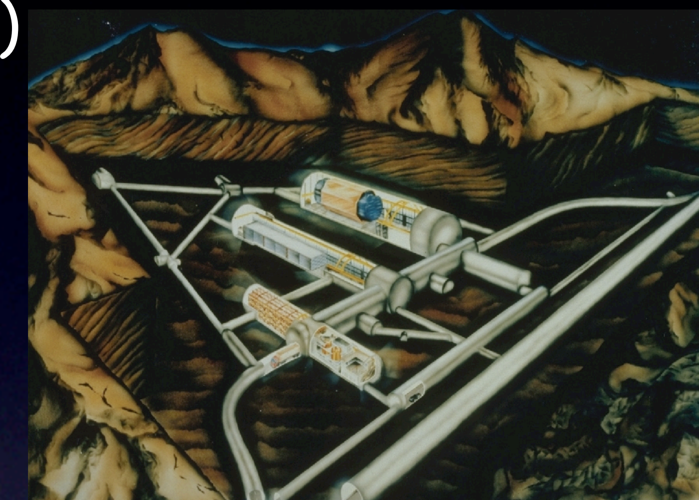

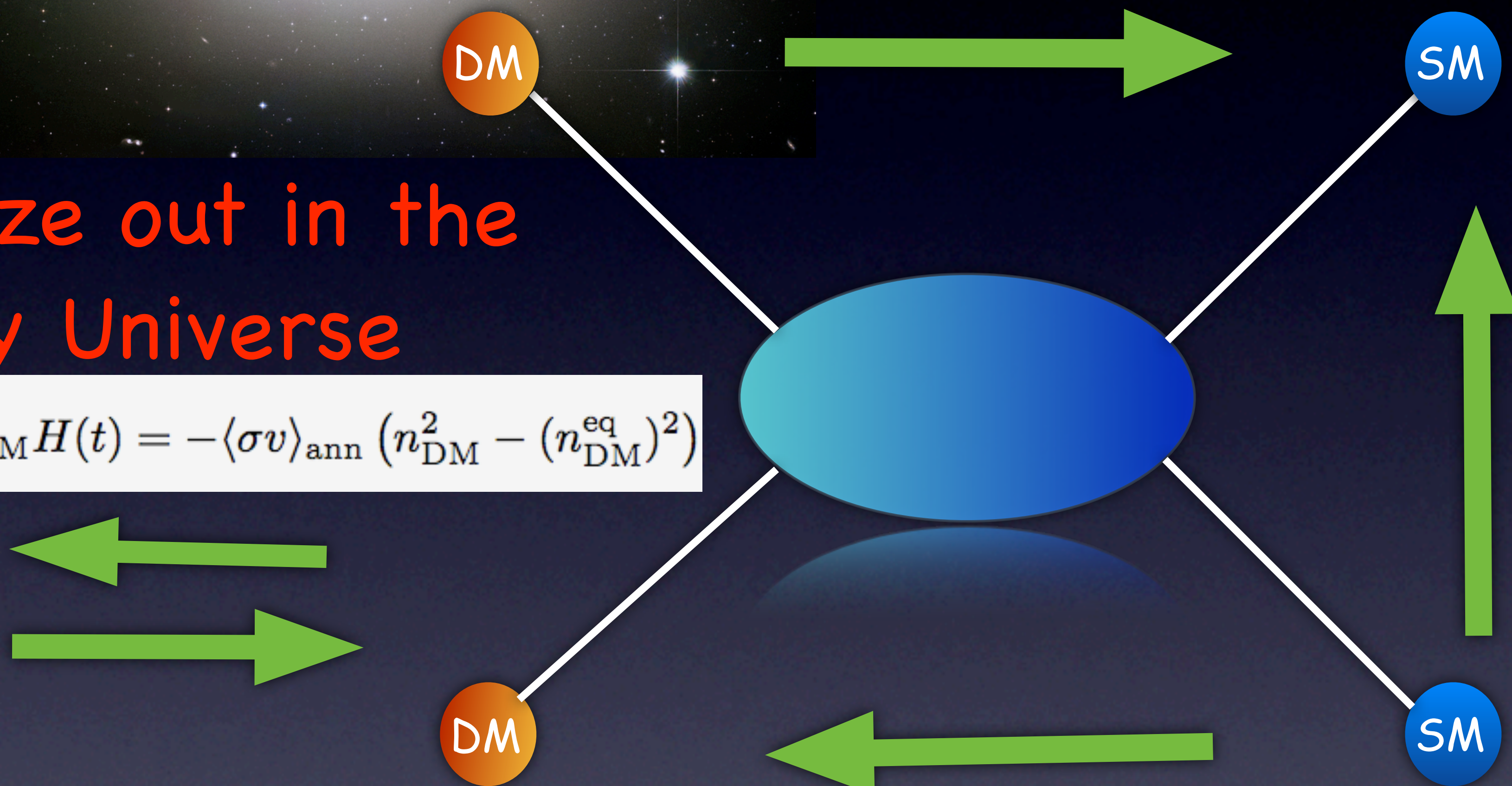

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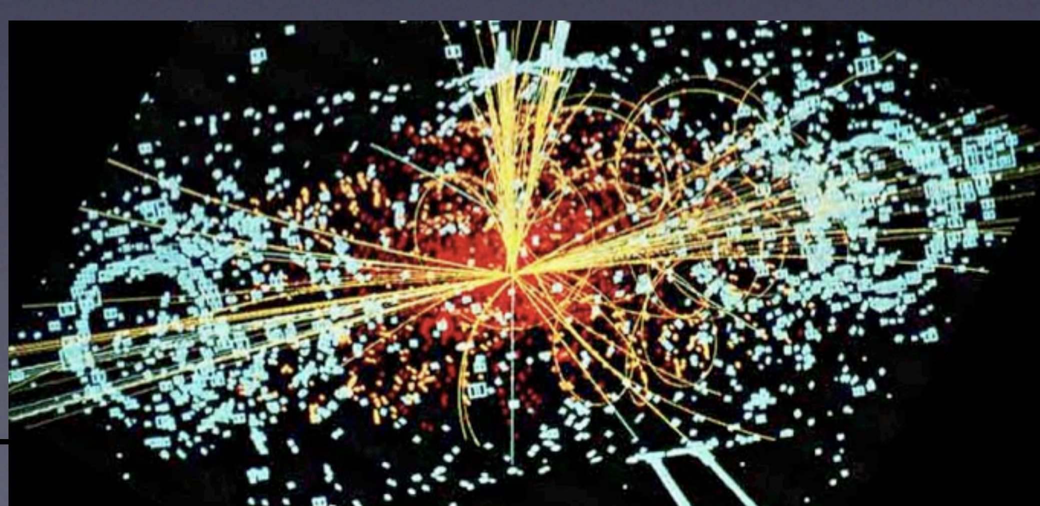
$$\frac{d\,n_{\rm DM}}{dt} + 3n_{\rm DM}H(t) = -\langle\sigma v\rangle_{\rm ann}\left(n_{\rm DM}^2 - (n_{\rm DM}^{\rm eq})^2\right)$$

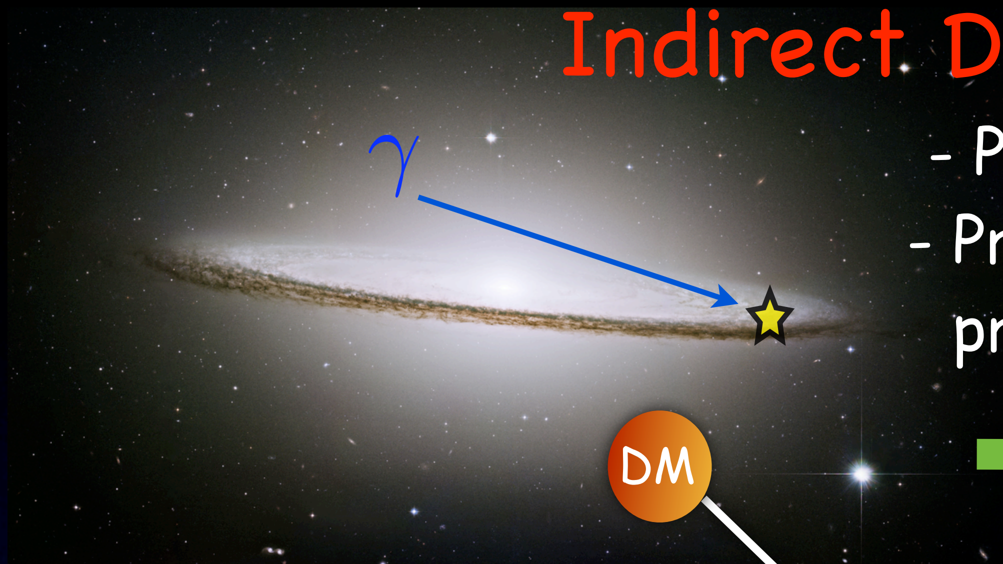
Direct Detection (DD)

Scattering off nuclei in underground detectors

Production @ colliders



Dark Matter Relic Abundance and Detection



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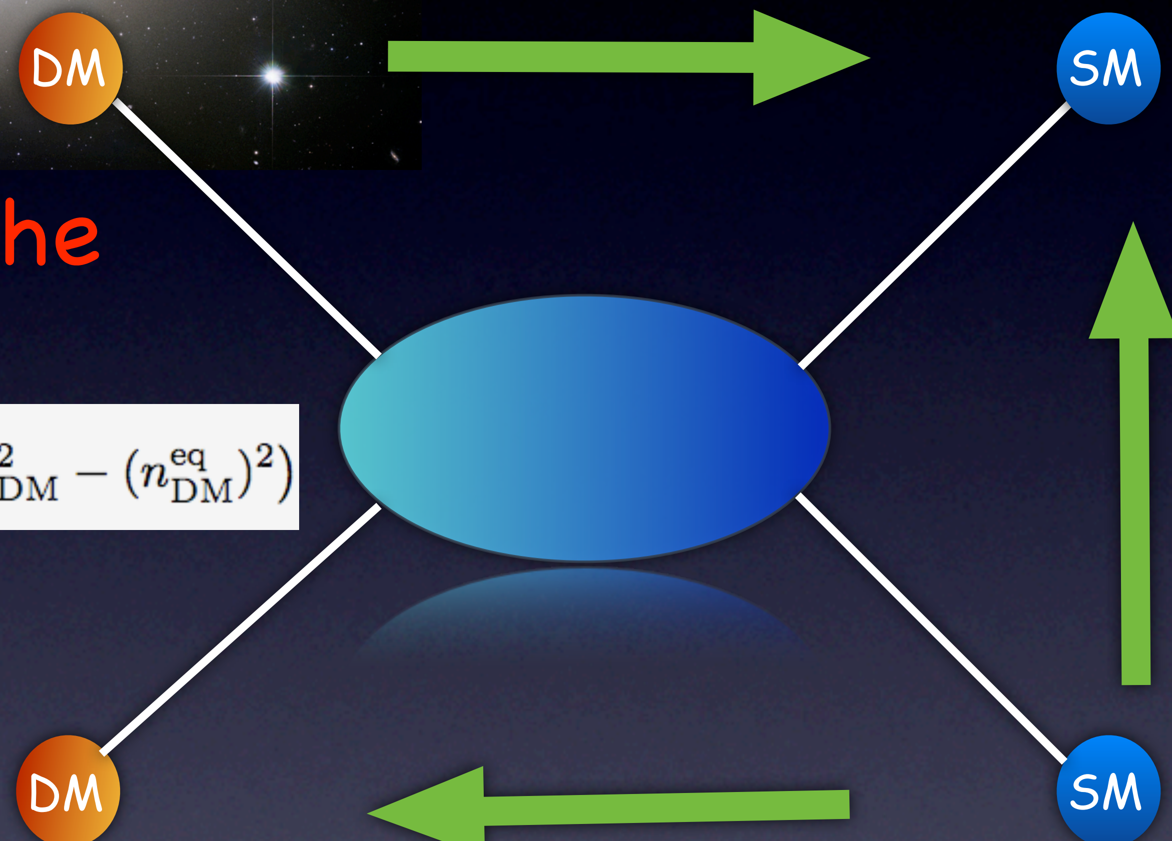

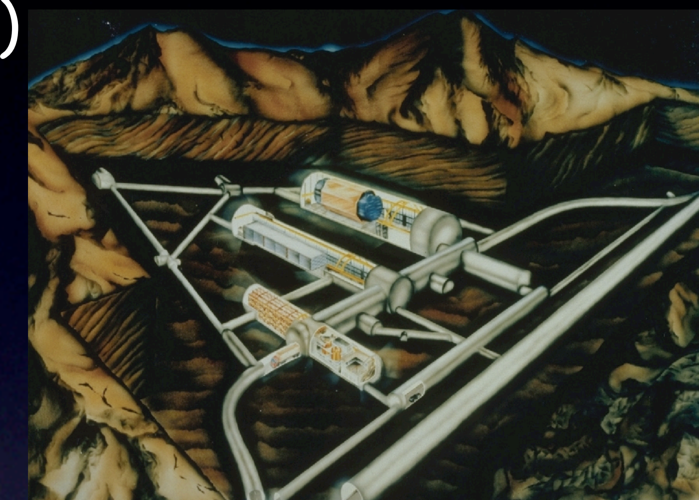

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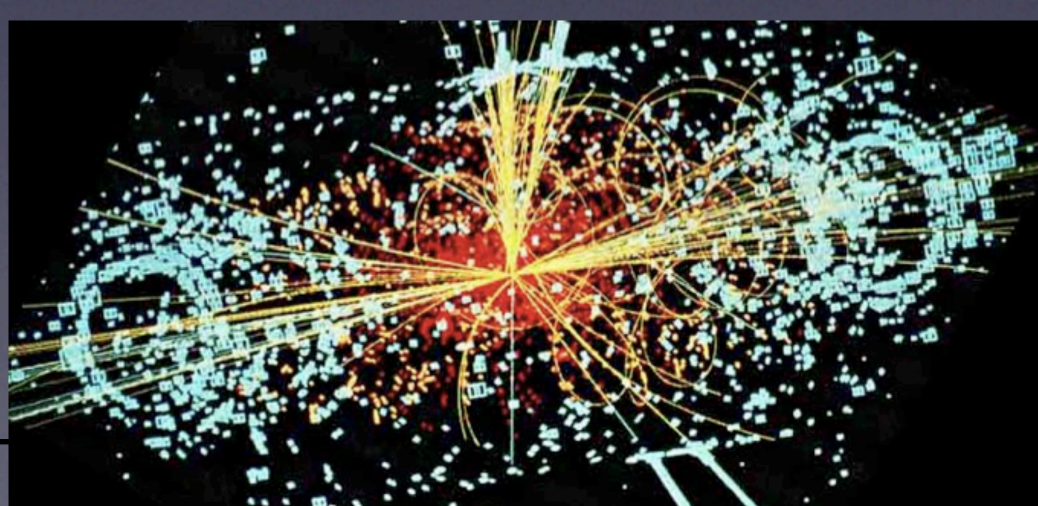


Production @ colliders

The same process can set the relic abundance, DD and ID (model dependent)

Singlet Scalar DM + SM

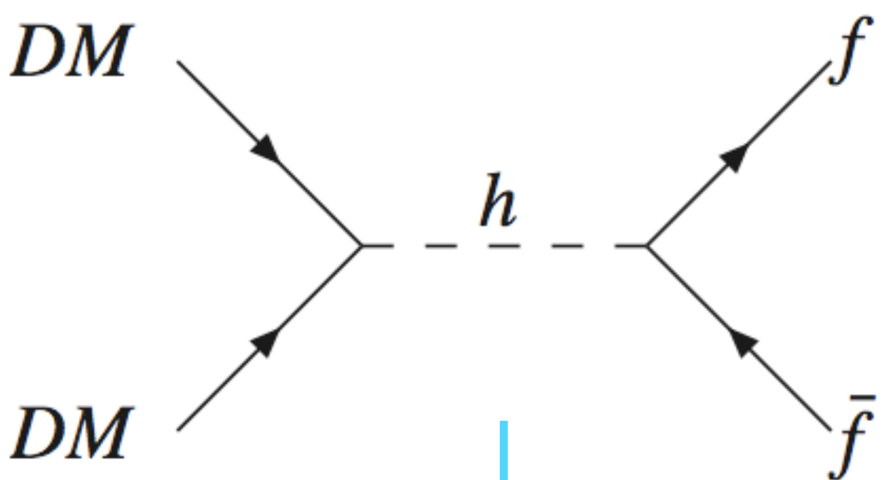
S. Andreas, T. Hambye and M.H.G.Tytgat
JCAP 0810:034 (2008), arXiv: 0808.0255

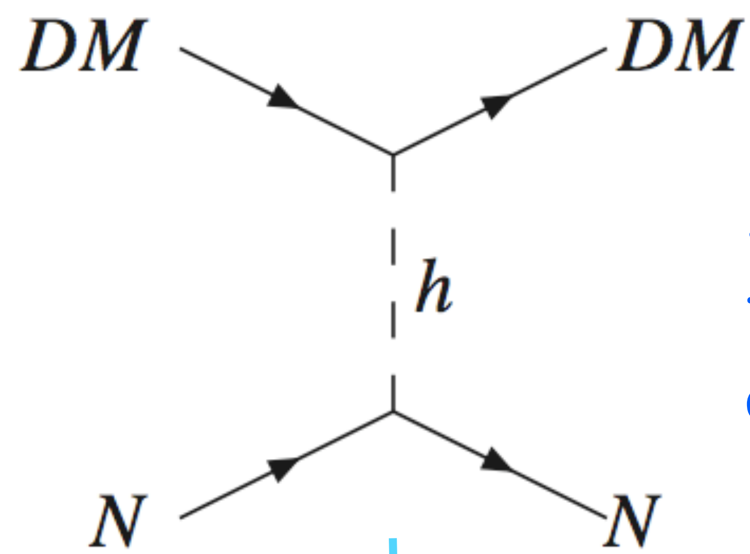
$$\mathcal{L} \ni \frac{1}{2}\partial^\mu S \partial_\mu S - \frac{1}{2}\mu_S^2 S^2 - \frac{\lambda_S}{4} S^4 - \lambda_L H^\dagger H S^2$$

$S \to -S$: Z_2 symmetry to stabilize S

$$m_S^2 = \mu_S^2 + \lambda_L v^2$$

Low mass region (mass in the range 1 - 20 GeV):





Same diagram fixes the relic abundance and the DD

$$\sigma(SS \to \bar{f}f)v_{\rm rel} = n_c \frac{\lambda_L^2}{\pi} \frac{m_f^2}{m_h^4 m_S^3}(m_S^2 - m_f^2)^{3/2}$$

$$\sigma(SN \to SN) = \frac{\lambda_L^2}{\pi} \frac{\mu_r^2}{m_h^4 m_S^2} f^2 m_N^2$$

$$R \equiv \sum_f \frac{\sigma(SS \to \bar{f}f)v_{\rm rel}}{\sigma(SN \to SN)} = \sum_f \frac{n_c m_f^2}{f^2 m_N^2 \mu_r^2} \frac{(m_S^2 - m_f^2)^{3/2}}{m_S}$$

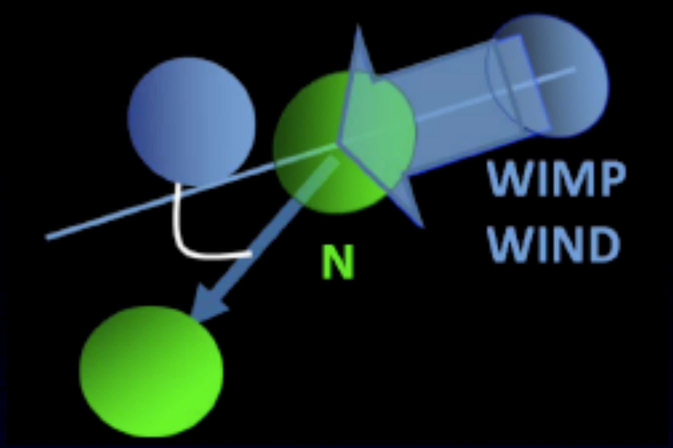
depends only on the DM mass

Simplest extension of the SM (McDonald 94', Pospelov et al. 01').
Can be seen as an effective or phenomenological model (i.e. Inert Doublet Model, Ma et al 78', Barbieri et al 06', Lopez Honorez et al. 07')

Direct Detection

- The two events of CDMSII-Ge and the DAMA modulated signal
- CoGeNT excess
- Xenon10 and Xenon100 exclusion limits
- Results for the singlet model and comments on the relic abundance

Differential Event Rate



$$\frac{dR}{dE_R} = \frac{\rho_{DM}}{m_{DM}} \frac{d\sigma}{dE_R} \eta(E_R, t) M_{det}$$

Detector mass

Particle and nuclear physics

$$\frac{d\sigma}{dE_R} \propto \frac{\sigma_n^0}{\mu_n^2} A^2$$

Astrophysics (source of uncertainties):

- SMH velocity distribution v0/c =10^-3
- local DM density 0.3 GeV/cm^3

$$\langle E_R \rangle \sim \text{keV} \left(\frac{m_{\mathcal{N}}}{\text{GeV}} \right) \left(\frac{m_{DM}}{m_{DM} + m_{\mathcal{N}}} \right)^2$$

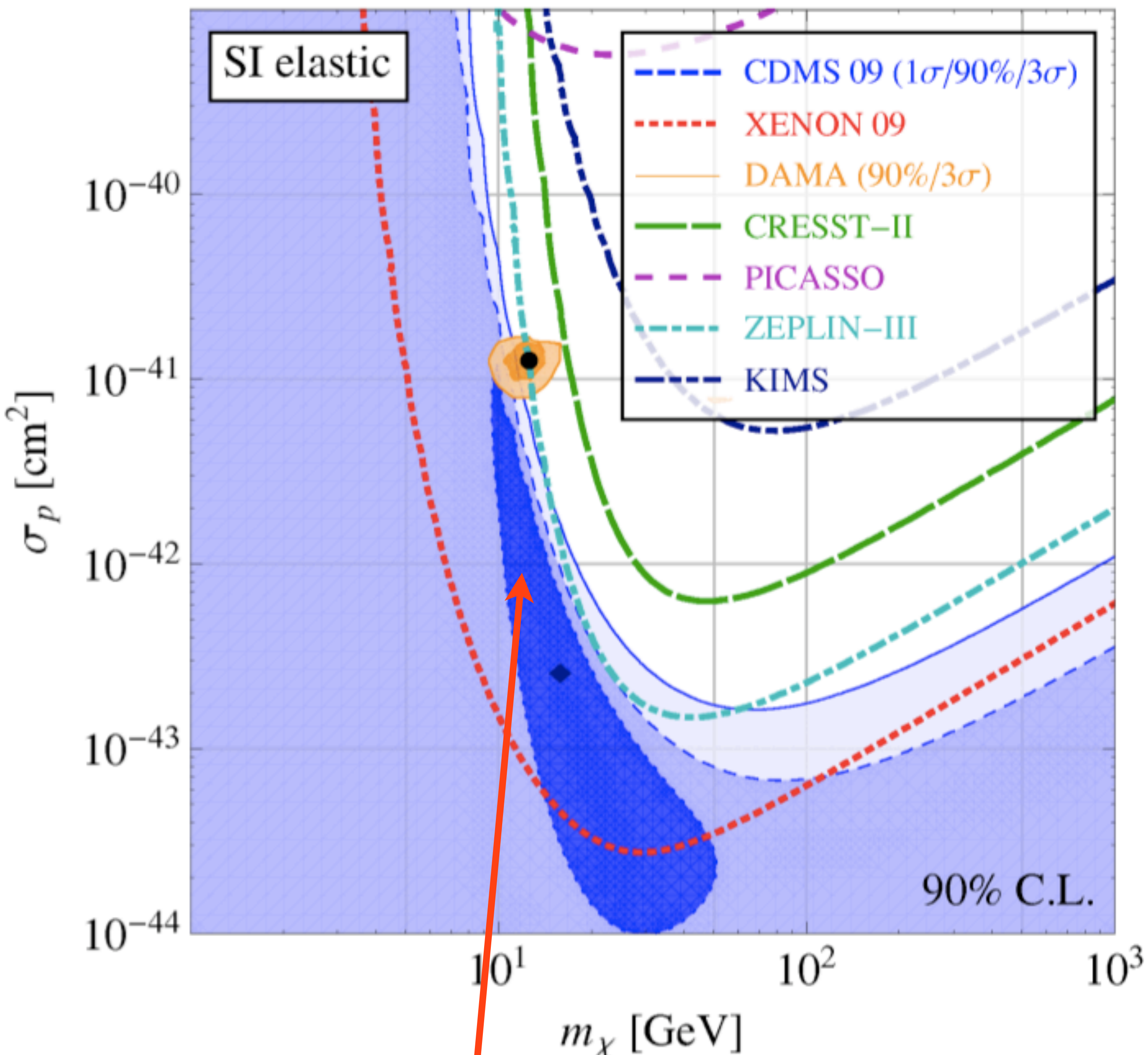
- Recoil energy is few keV -> low energy threshold to be more sensitive to the signal
- Recoil energy of few keV -> good understanding of the background
- Rare process -> large detector mass and long exposure time

CDMS-II

CDMSII Collaboration, Z.Ahmed et al.
Science 327 (2010), arXiv:0912.3592

CDMS-II run ~ 600 kg-day of Ge

2 events @ $1.64\ \sigma$ low significance



Exclusion bound @ 90% C.L. of CDMS-Si
(Akerib et al. PRL96 2005, astro-ph/0509259)
Important for light DM particles because Si is a light nucleus

preferred low mass range for a WIMP 10 - 50 GeV @ 73% C.L.

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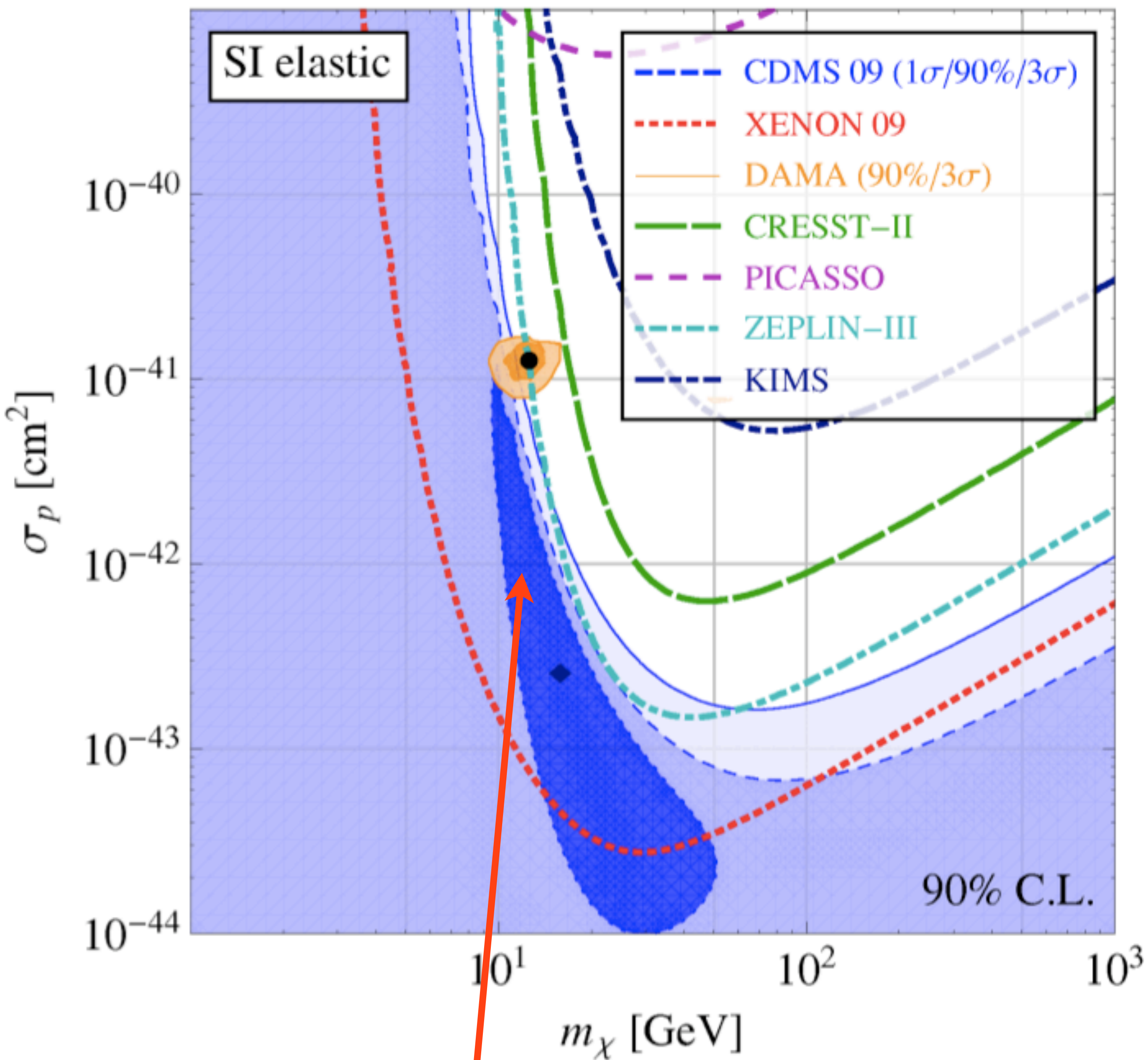

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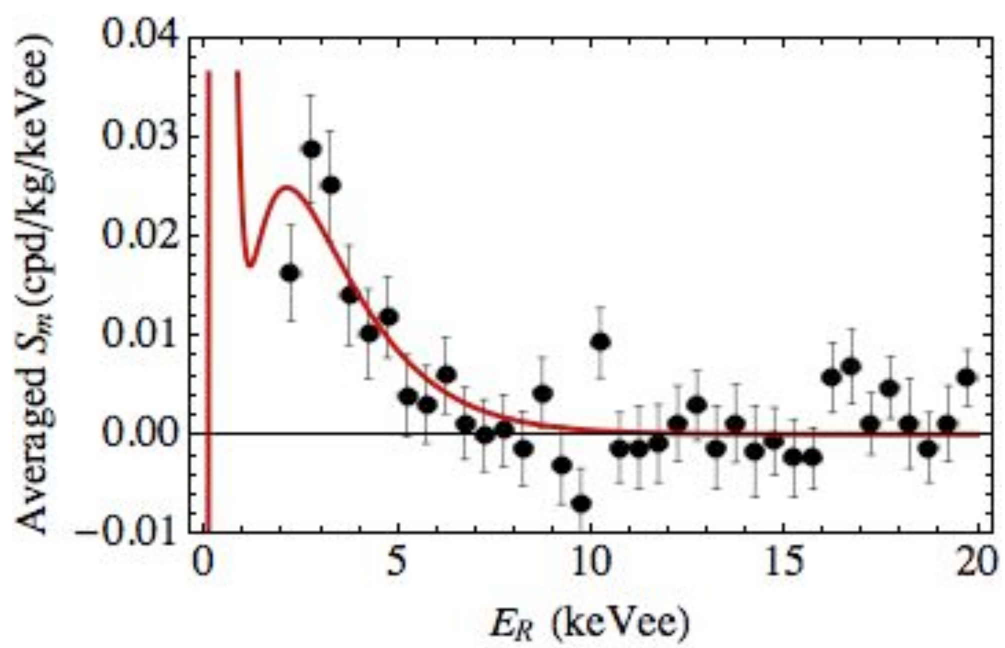
DAMA/LIBRA as light WIMP signal:
scattering on Na if there is no channeling else on I with channeling



$$m_{DM} = 12\ \text{GeV} \qquad \sigma_n^0 = 1.5 \times 10^{-41}\text{cm}^2$$

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J. Kopp, T. Schwetz and J. Zupan
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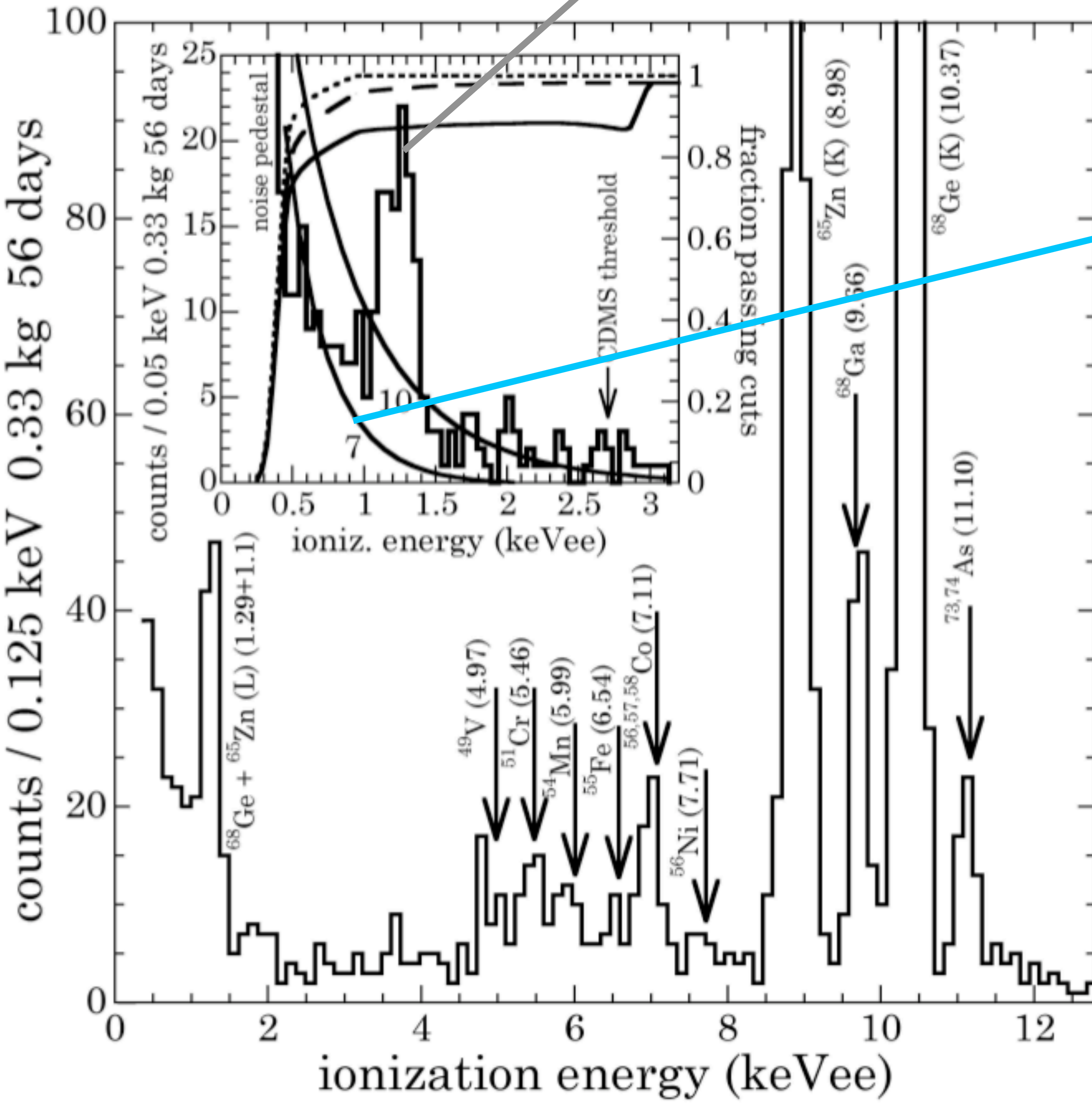
CoGeNT

C.E. Aalseth et al. arXiv: 1002.4703

- Ge detectors
- data analysis: 0.33 kg x 56 days
- very low threshold 0.4 -3.2 keVee (~ 1.1-11 keV) (compared to CDMS-II 10-100 keV)
- very good energy resolution

Radioactive peaks



~ 100 events of unknown origin

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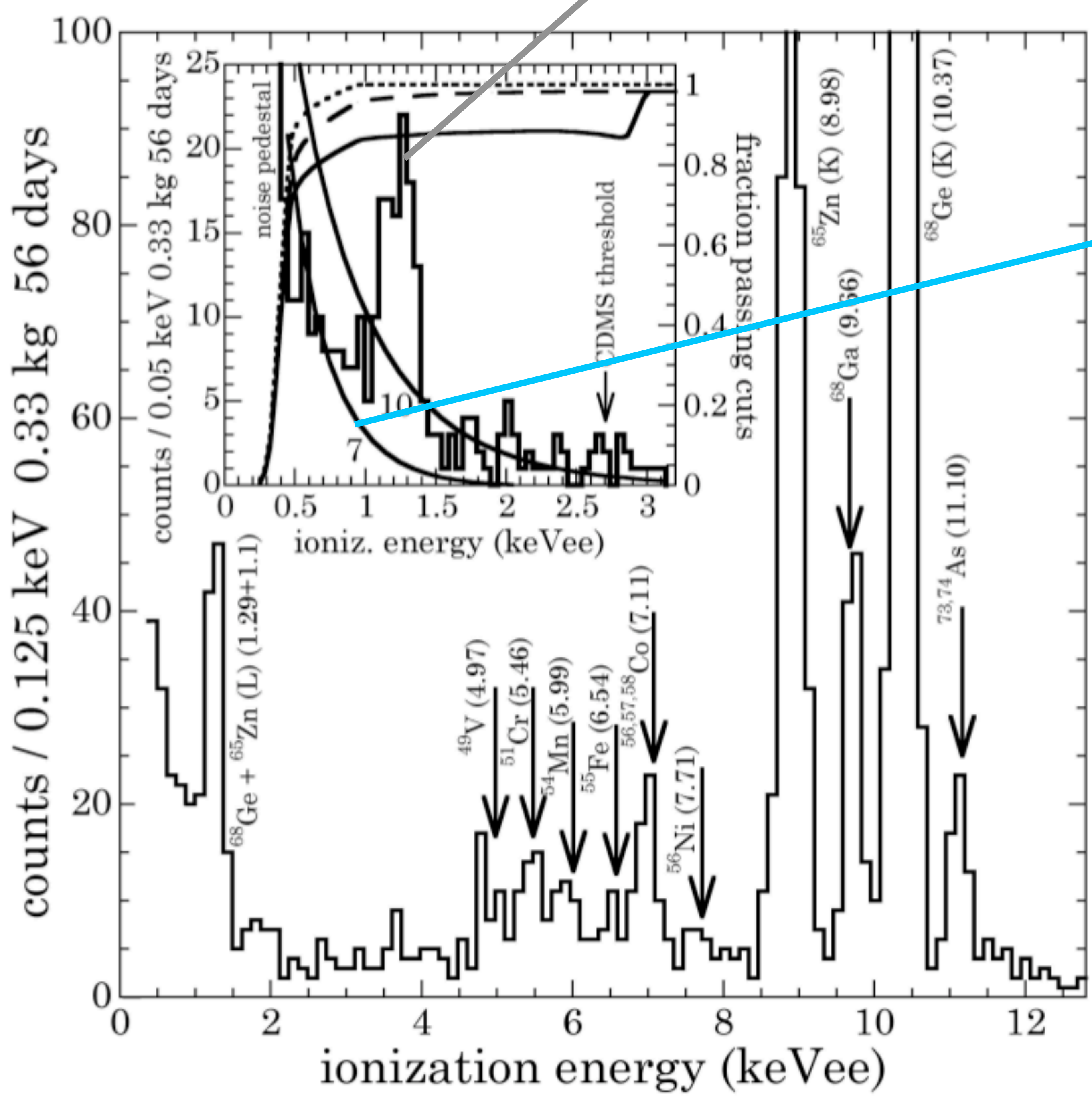

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Background or dark matter signal ?

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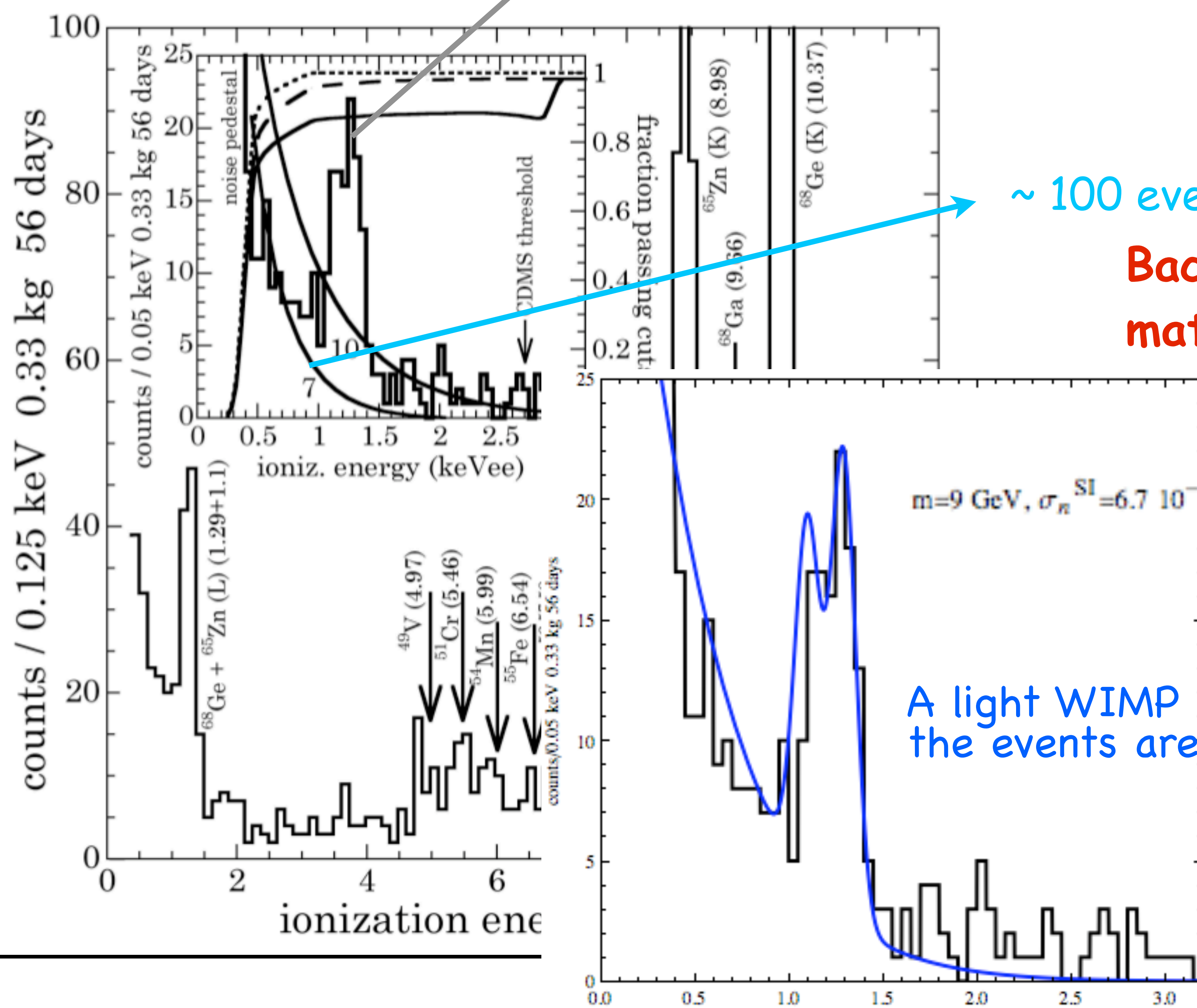

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Background or dark matter signal ?

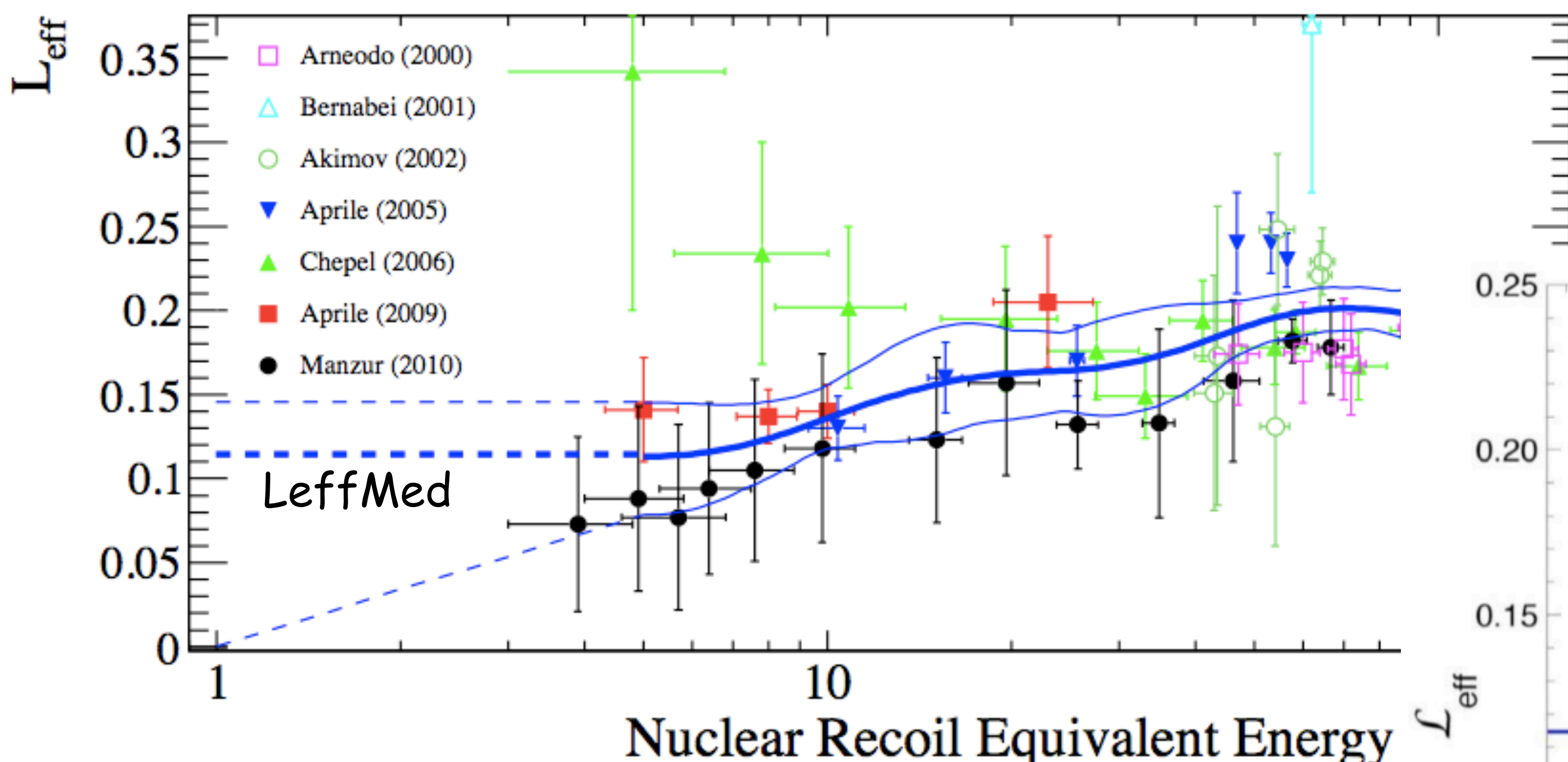
A light WIMP can fit CoGeNT supposing the events are genuine DM signal

Xenon10 and Xenon100

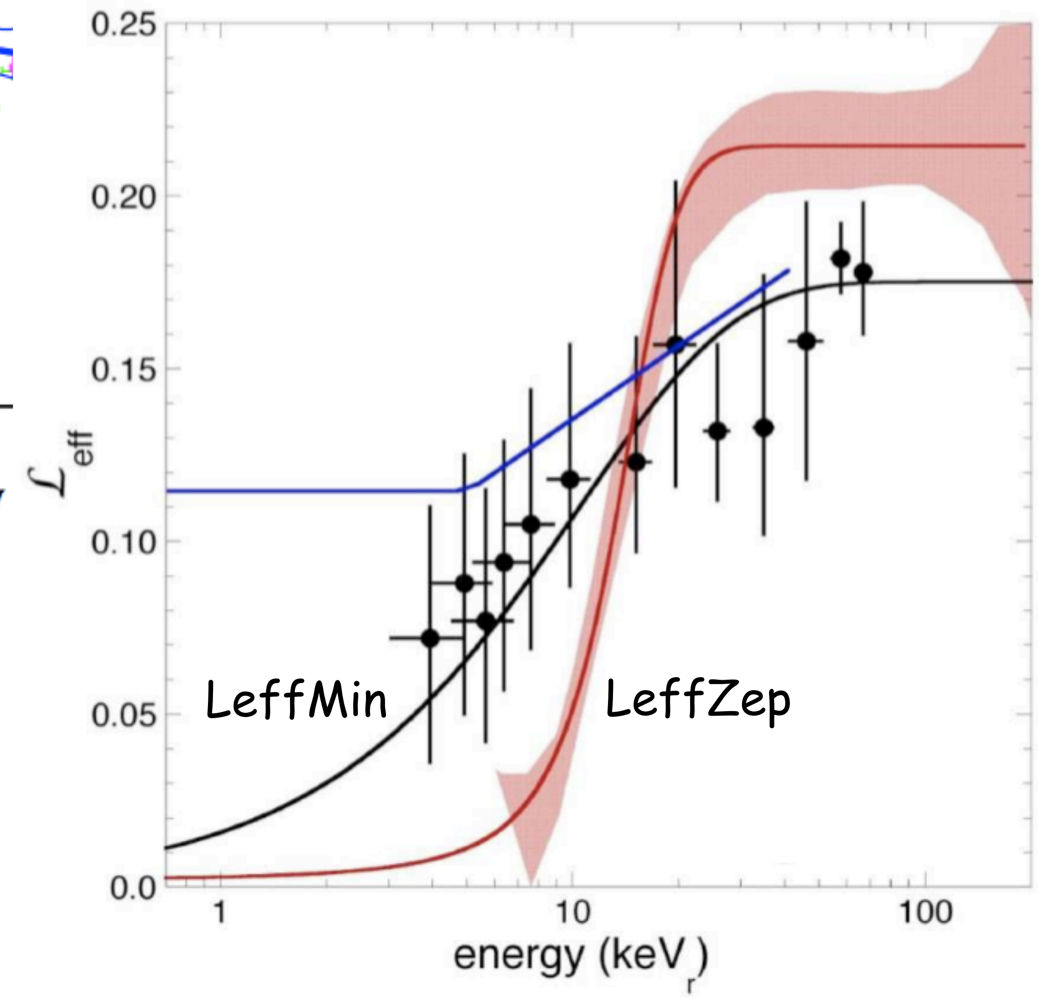
Xenon10, J.Angle et al, PRD80 (2009), arXiv:0910.3698
Xenon100, E.Aprile et al., PRL105 (2010), arXiv:1005.0380

- Two phase Xe detectors
- Use of ionization and scintillation to disentangle background and nuclear recoil
- 4.5 - 26 keVee energy range ~ 23-140 keV

Exclusion limits affected by large uncertainties on Leff, which is the conversion factor from PE (scintillation signal that measures the photoelectron caused by nuclear recoil) to proper nuclear recoil energy



Collar and McKinsey, arXiv:1005.0838

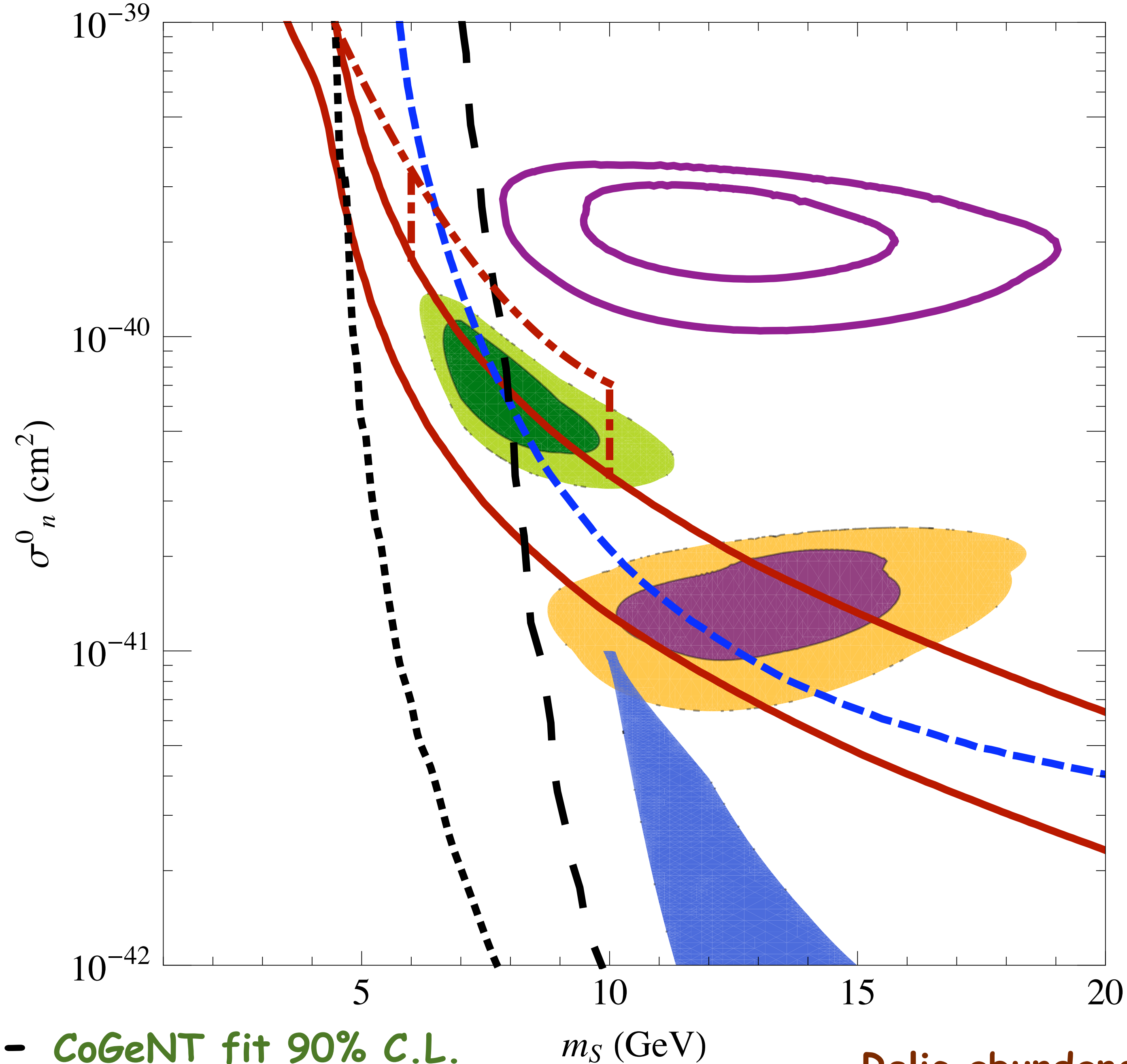


Xenon10 exclusion limits@90% C.L.:
- LeffMed and LeffMin
- 13 events and extended threshold to 2 keVee

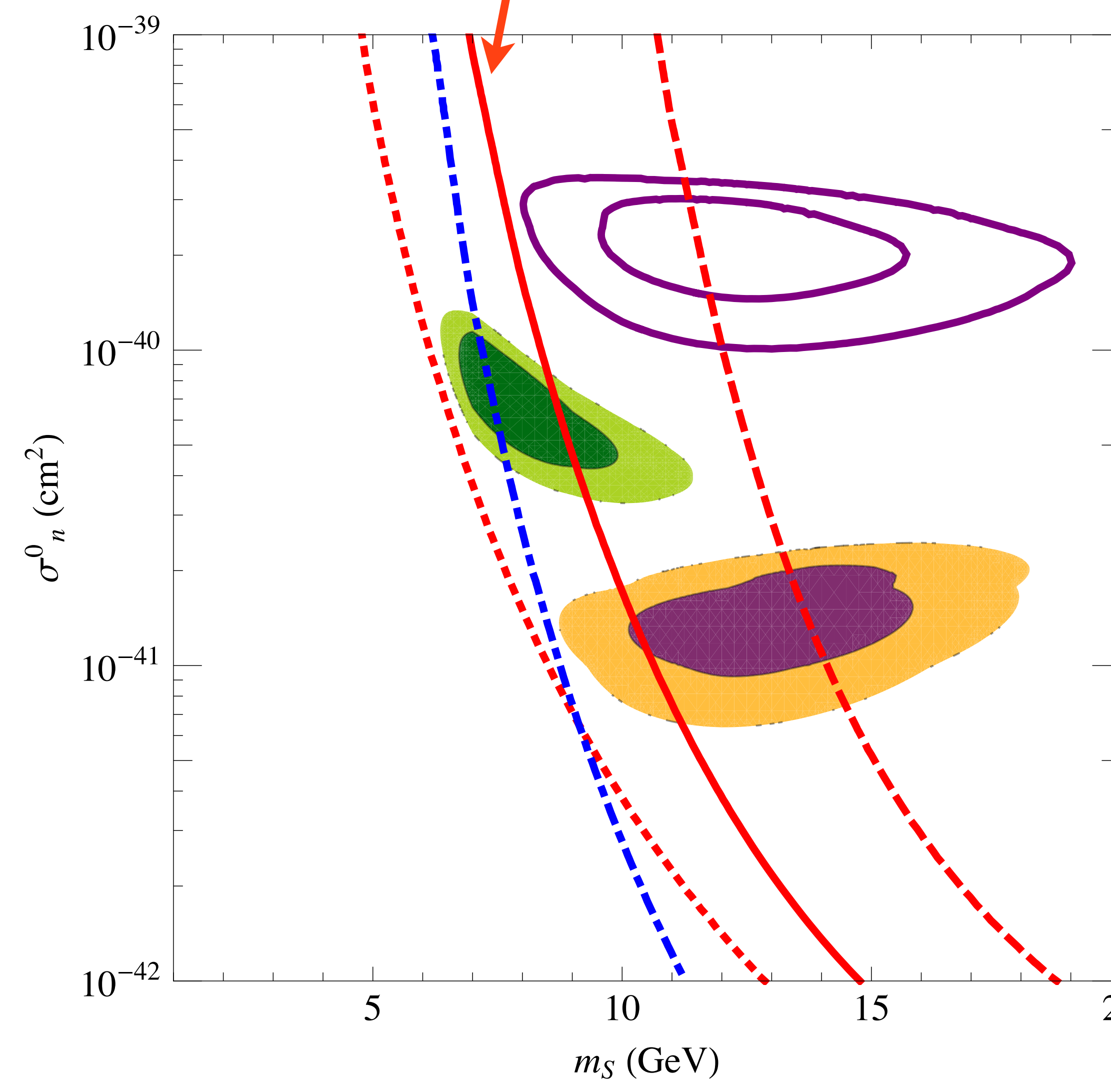
Xenon100 exclusion limits@90% C.L.:
- LeffMed, LeffMin and LeffZep
- 11.2 days x 40 kg x 0.8 efficiency = 170 kg days
- 0 event seen
- Considered Poisson fluctuations in the number of photon detected

S. Andreas, C.A., T. Hambye, F. Ling and M. Tytgat, Phys.Rev.D82(2010), arXiv:1003.2595

Singlet Scalar DM concordance



Xenon100 with LeffZep, LeffMIn, LeffMed



- CoGeNT fit 90% C.L. and 99.9% C.L.

- DAMA fit no channeling 90 and 99.9% C.L.

- Dama channeling at 99.9% C.L. and 99.9% C.L.

Relic abundance within WMAP

CDMS-Si 90% C.L.

- CDMS-II at 78% C.L.

Xenon10 limits with different Leff

From N. Bozorgnia, G. Gelmini and P.Gondolo, arXiv:1006.3110, preferred unchanneled region for DAMA

Gamma-ray constraints on light DM with the first 11 months of Fermi survey

Gamma-ray Flux as a function of the energy

$$\frac{d\Phi_\gamma}{dE} = \frac{d\Phi_\gamma^{\rm PP}}{dE} \times \Phi^{\rm cosmo}$$

Gamma-ray flux injected by DM annihilation

$$\frac{d\Phi_\gamma^{\rm PP}}{dE} = \frac{1}{4\pi}\frac{<\sigma v>_{\rm ann}}{2M_{DM}^2}\sum_f \frac{dN_\gamma^f}{dE} BR_f$$

Additional factor of 1/2 in case of non self-conjugate DM

Astrophysical factor
- the functional form depends on the studied signal
- related to the density distribution of DM
- considered hereafter a NFW DM density profile

For light DM candidates that can explain the DD 'excess' the photon flux is enhanced by the 1/M^2 factor

Two different signals considered to constrain the singlet model:

1) Diffuse emission from Dwarf Spheroidal Galaxies

2) Diffuse emission from extragalactic background

Gamma-ray spectra

C.A. and M.Tytgat, arXiv:1007.2765

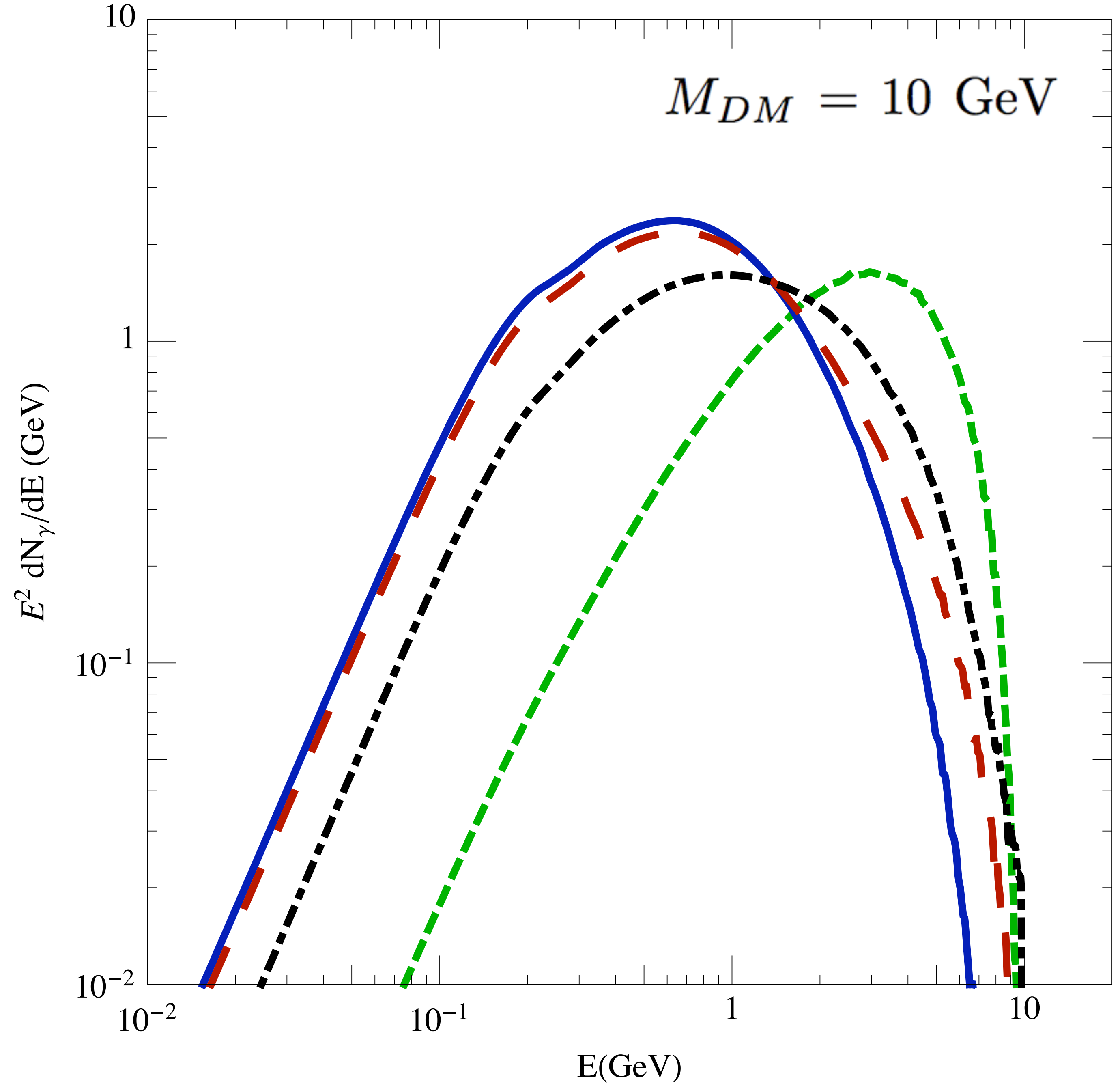
$$\frac{dN_\gamma}{dE} = \sum_f \frac{dN_\gamma^f}{dE} BR_f$$

Scalar singlet (H like coupling)

	Branching ratios			
m_S	$b\bar{b}$	$c\bar{c}$	$\tau^+\tau^-$	others
20 GeV	85 %	5 %	9 %	$\sim$ 1 %
10 GeV	83 %	7%	10 %	$\lesssim$ 1 %
5 GeV	16 %	36 %	42 %	$\sim$ 5 %
2 GeV	\	69 %	22 %	$\sim$ 9 %

$BR_{\tau^+\tau^-} = 100\%$

$BR_{b\bar{b}} = 100\%$



DM with Z-like coupling

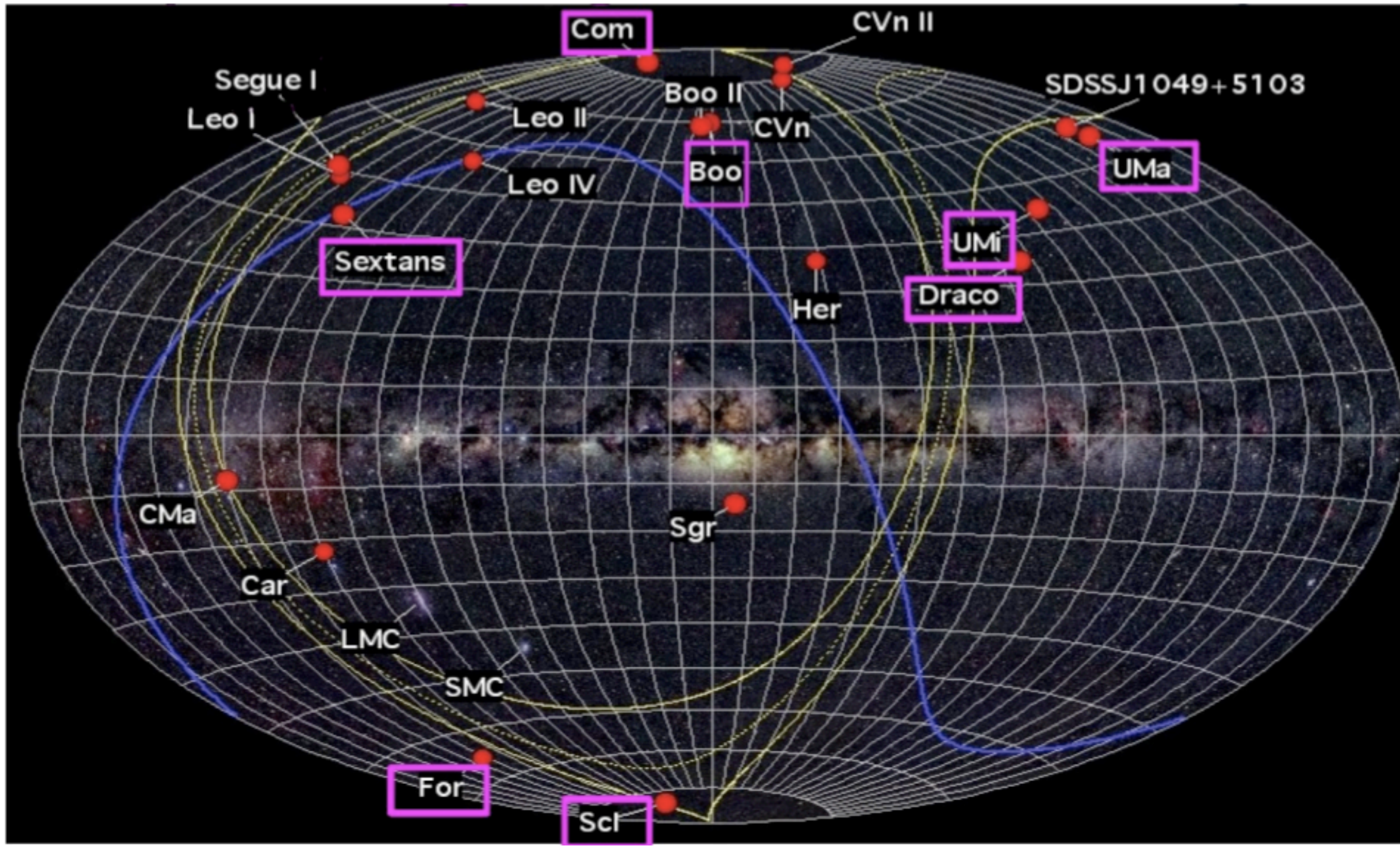
(Dirac fermion mediated by a Z' can account for the CoGeNT/DAMA region, Mambrini arXiv:1006.3618)

$$BR_{b\bar{b}} \sim 3 \times BR_{l^\pm} \sim 13\%$$

Dwarf Spheroidal Galaxies (dSphs)

Fermi-LAT collaboration: A.A. Abdo et al. Astrophys.J 712 (2010), arXiv:1001.4531

- expected to be DM dominated
  M/L ~ 100-1000
- small content of dust and gas
- expected to be free from other gamma-ray astrophysical sources



Local Group dSphs

Fermi-LAT benchmarks, choosen because of the high galactic coordinates

$$\Phi^{\rm cosmo} = \int_{\rm l.o.s.} dl(\psi)\rho^2(l(\psi))$$

S. Andreas, C.A., T. Hambye, F.S.Ling and M.Tytgat, Phys.Rev.D82 (2010), arXiv:1003.2595

Flux for the singlet at low masses and expected Fermi flux

	Ursa Minor		Draco	
m_S and BR	$\Phi_{\rm pred}({\rm cm}^{-2}{\rm s}^{-1})$	$\Phi_{\rm lim}^{95\%{\rm CL}}({\rm cm}^{-2}{\rm s}^{-1})$	$\Phi_{\rm pred}({\rm cm}^{-2}{\rm s}^{-1})$	$\Phi_{\rm lim}^{95\%{\rm CL}}({\rm cm}^{-2}{\rm s}^{-1})$
10 GeV ${\rm BR}(SS \to \tau^+\tau^-) \simeq 10\%$ ${\rm BR}(SS \to b\bar{b} + c\bar{c}) \simeq 90\%$	8.5×10^{-10}	7.8×10^{-10}	1.6×10^{-9}	1.6×10^{-9}
6 GeV ${\rm BR}(SS \to \tau^+\tau^-) \simeq 20\%$ ${\rm BR}(SS \to b\bar{b} + c\bar{c}) \simeq 80\%$	1.5×10^{-9}	1.0×10^{-9}	2.8×10^{-9}	1.7×10^{-9}

Talk of Grande @ IDM 2010 extended to 24 months of data and to lower DM masses

Isotropic Gamma-ray Background Radiation (IGRB)

C.A. and M.Tytgat, arXiv:1007.2765

Optical depth: describes how the Universe is transparent to photon emitted at $E' = E(1+z')$ for light DM can be neglected

$$\frac{d\Phi_\gamma}{dE} = \int_0^\infty dz' \frac{e^{-\tau(E',0,z')}}{H(z')(1+z')^4} \frac{d\Phi_\gamma^{\rm PP}}{dE'} \mathcal{B}^2(z')$$

$$H(z)(1+z) = H_0 h(z)(1+z)$$

$$\Phi^{\rm cosmo}$$

$$\mathcal{B}(z) = \rho_c \Omega_{DM} (1+z)^3 \sqrt{1 + \mathrm{B}(z)}$$

takes into account the dark matter density profile at a given redshift z and the boost from structure formation

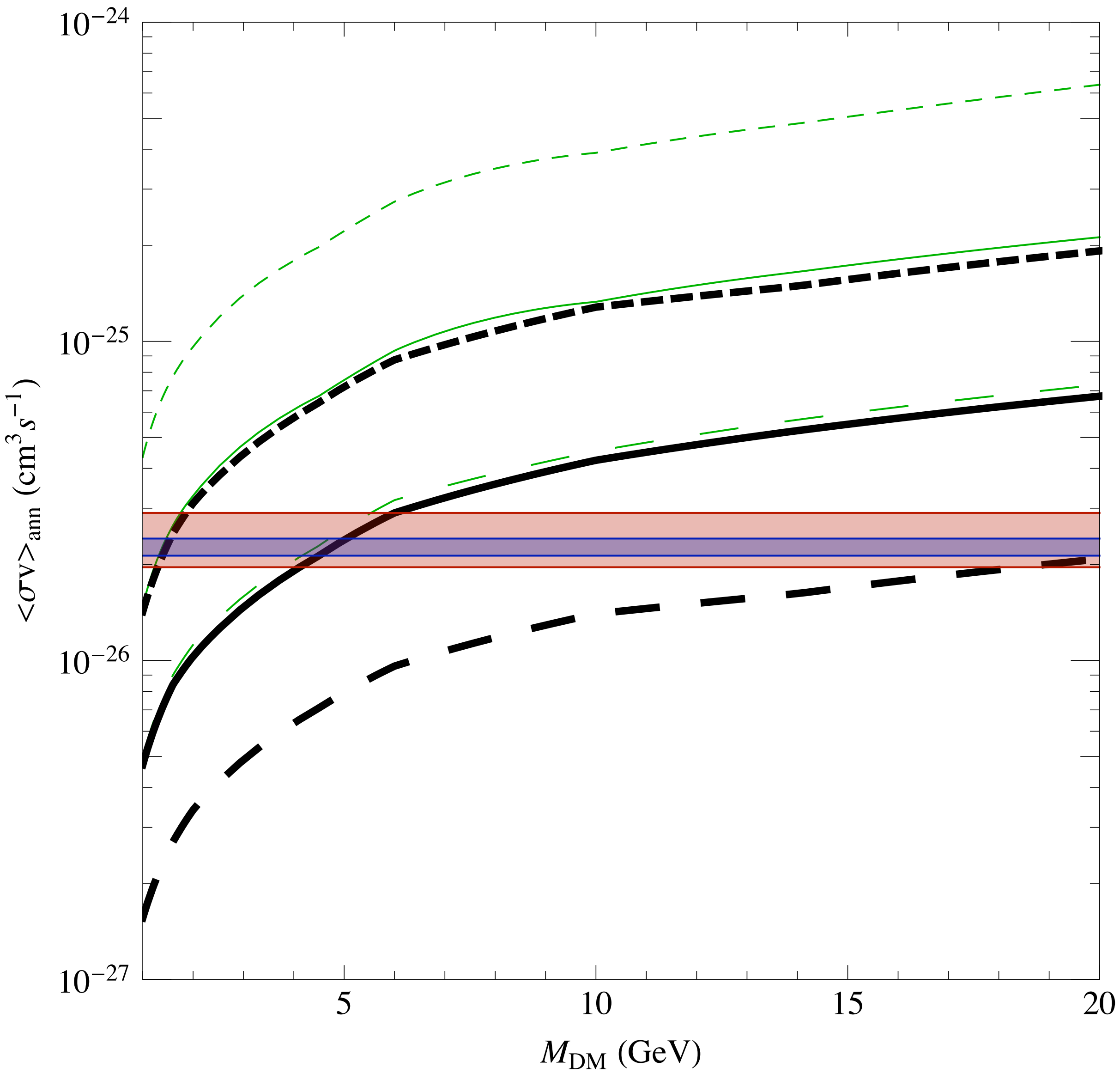
Press-Schechter formalism for the non-linear growth of dark matter halos

$$B(z) = \frac{\Delta_{vir}}{3\rho_c \Omega_M} \int_{M_{\rm min}}^\infty dM\, M \frac{dn}{dM} F_{\rm NFW}(c_{vir}(z, M))$$

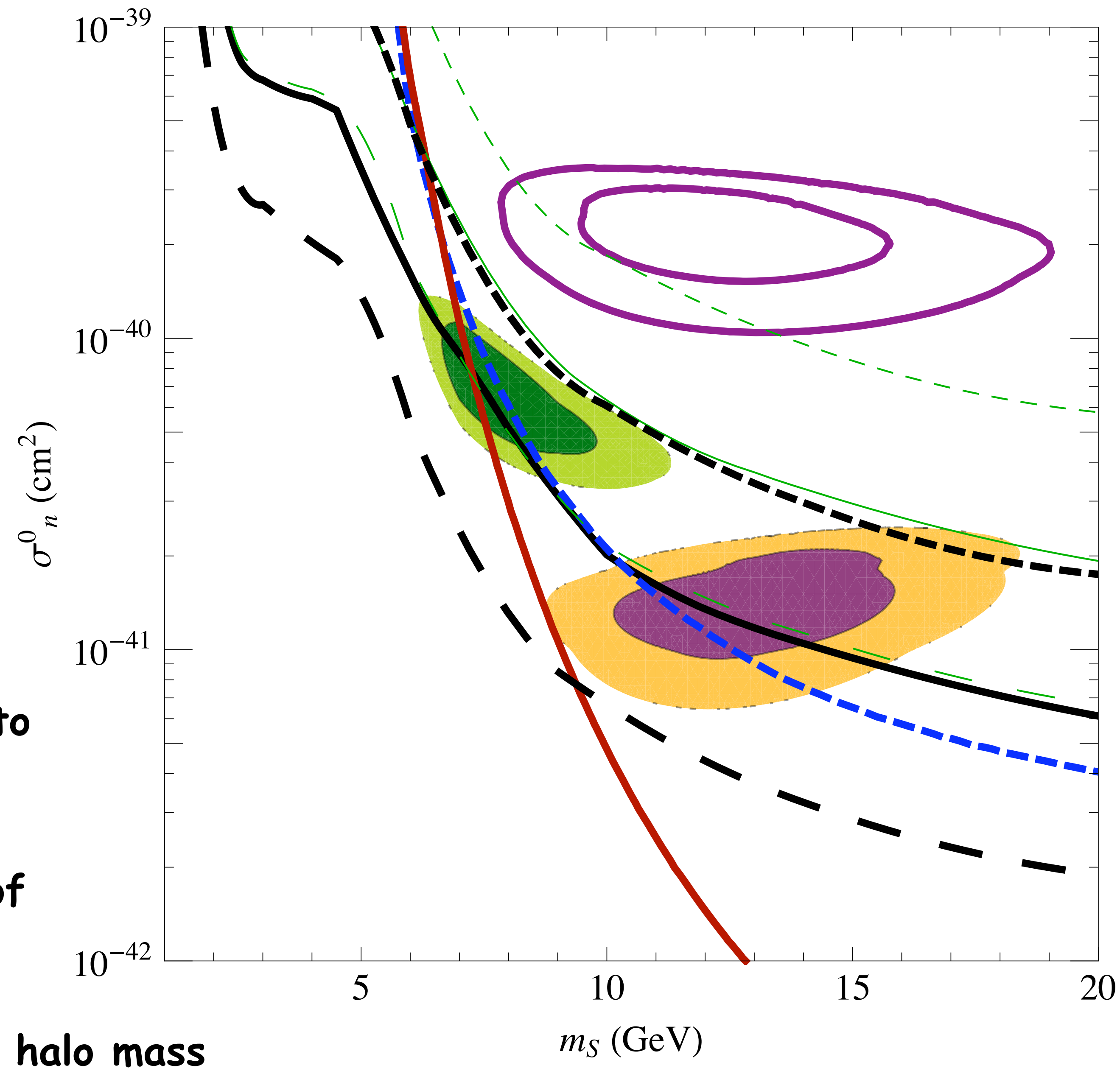
$$\Phi^{\rm cosmo}$$ Large source of uncertainties

Upper-bounds @ 95%C.L. for the scalar singlet

C.A. and M.Tytgat, arXiv:1007.2765



$$R \equiv \sum_f \frac{\sigma(SS \to \bar{f} f) v_{\rm rel}}{\sigma(SN \to SN)} = \sum_f \frac{n_c m_f^2}{f^2 m_N^2 \mu_r^2} \frac{(m_S^2 - m_f^2)^{3/2}}{m_S}$$



$M_{\rm min} = 10^{-6} M_\odot$

$M_{\rm min} = 10^{-8} M_\odot$

$M_{\rm min} = 10^{-4} M_\odot$

- Uncertainties related to the minimal halo mass
- depends on the kinetic decoupling temperature of the DM candidate

$C_{\rm PL}$

$C_{\rm WMAP}$

- dependence on Cvir and the halo mass uncertain (Bullock 01' and Maccio 08')

Summary

Singlet scalar Dark Matter 'State of the art':

- Minimal extension of the SM (bottom-up approach to DM)

- Account for the DAMA signal and the CoGeNT (Cresst) excess and for the same range of parameters provides also the good relic abundance

- Strong constraints from gamma-ray data of the Fermi-LAT satellite:
  1) Dwarf Spheroidal Galaxies
  2) Diffuse extragalactic background depending on the astrophysical assumptions

Low mass direct detection region can be ruled out at 95% C.L.

Other constraints on light DM candidates:

- **Synchrotron radiation from the Galactic Center and/or Galaxy Clusters** (multi-wavelengths analysis interesting) see i.e. Hooper 08', Regis 08', Borriello 08', Bell 10', C. Boehm et al 02'

- **Anti-protons** (J. Lavalle arXiv:1007.5253, W.Y. Keung I.Low and G.Shaughnessy arXiv: 1010.1774)

- **Neutrinos** (Andreas et al, arXiv:0901.1750)

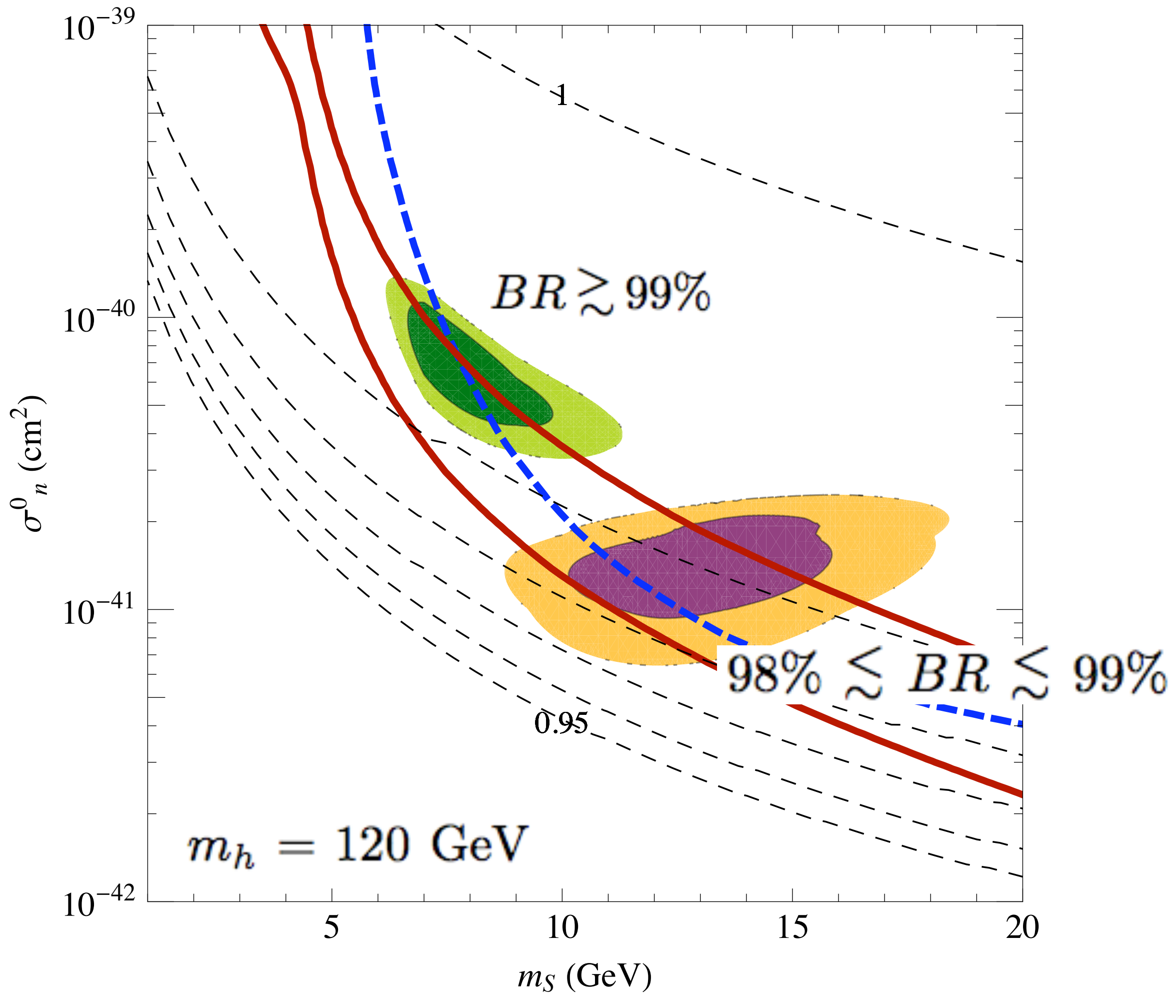
Thanks !

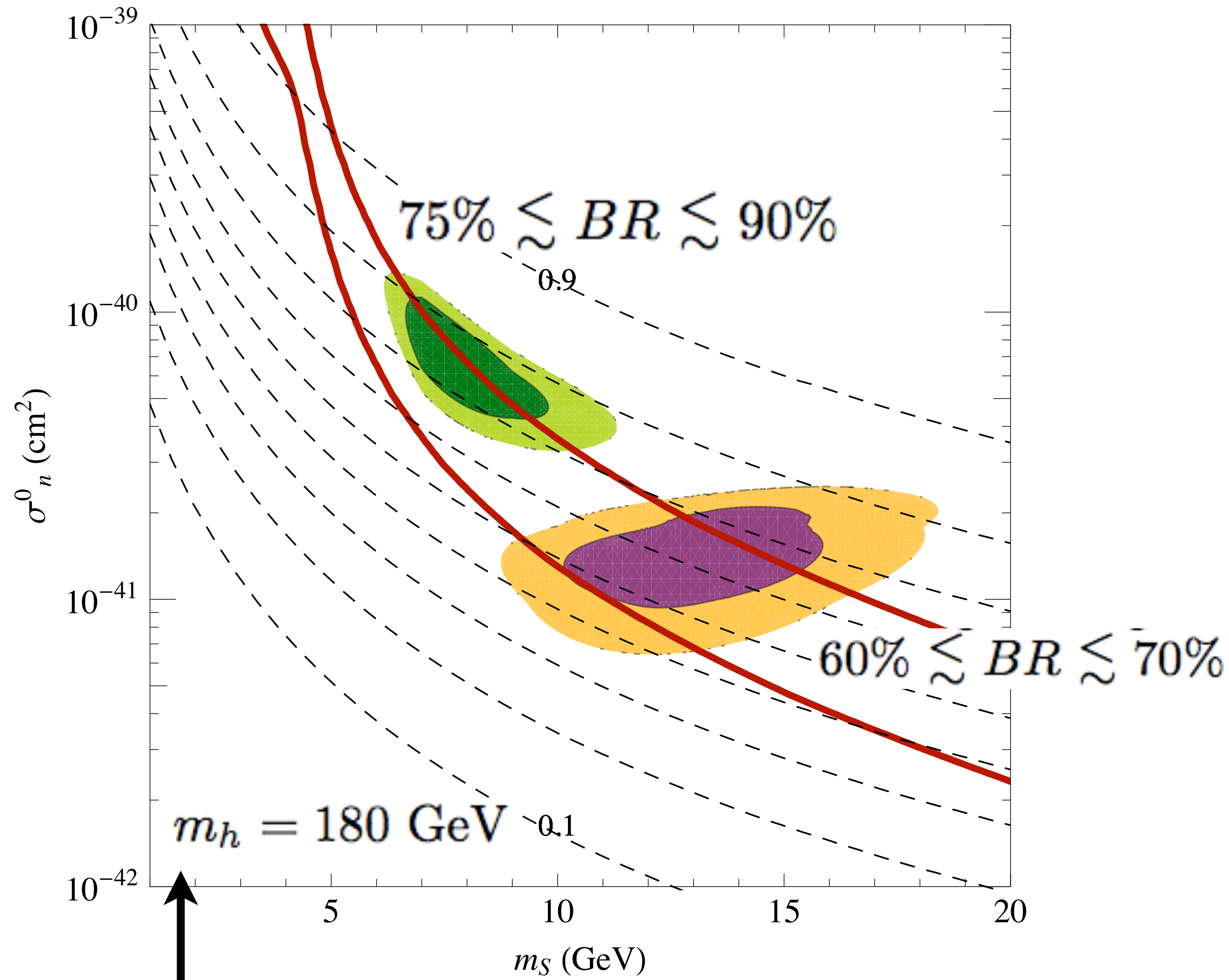
Back-up slides

S. Andreas, C.A., T. Hambye, F. Ling and M. Tytgat, Phys.Rev.D82(2010), arXiv:1003.2595

Implications in Higgs invisible width and LHC

- From CDMS-II, CoGeNT and DAMA preferred WIMP mass < MH/2
- If the interaction DM-nucleus through Higgs t channel is the dominant one
- The Higgs will decay mainly into DM particles -> invisible decay

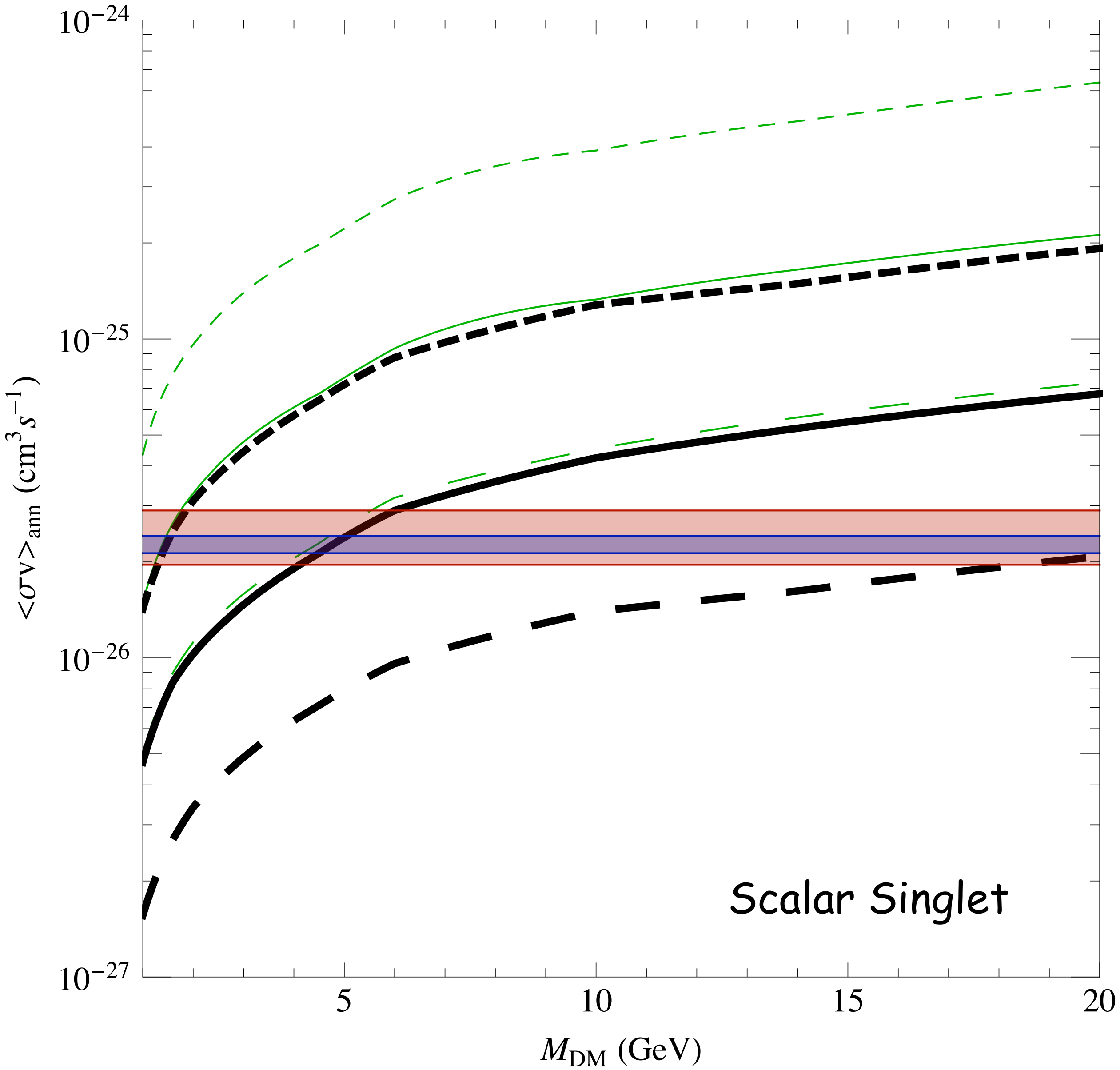


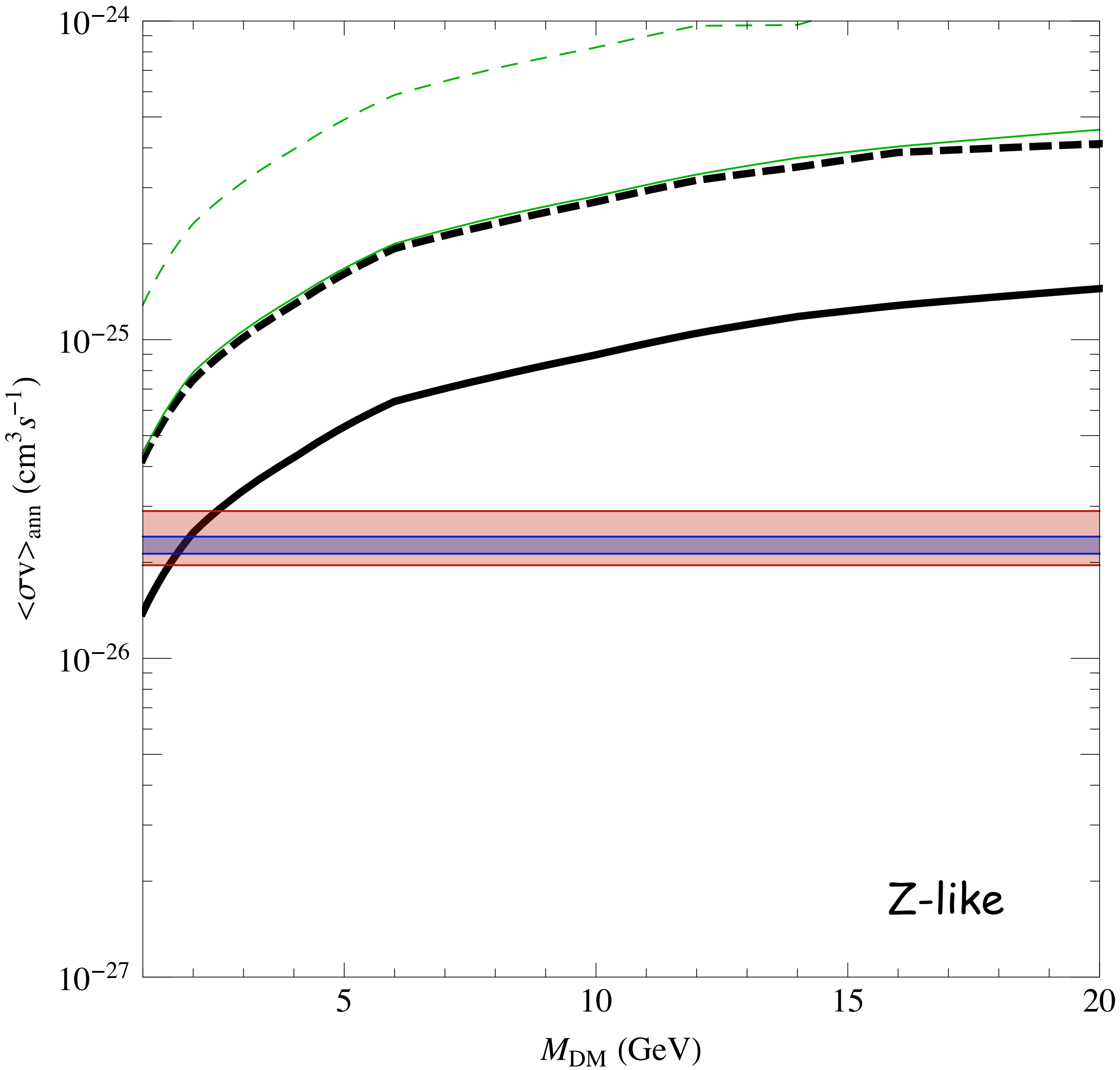


Regions can be distinguished by measuring the Higgs invisible decay @ LHC (10% expected sensitivity)

Comparison with a Dirac candidate with Z-like couplings

C.A. and M.Tytgat, arXiv:1007.2765



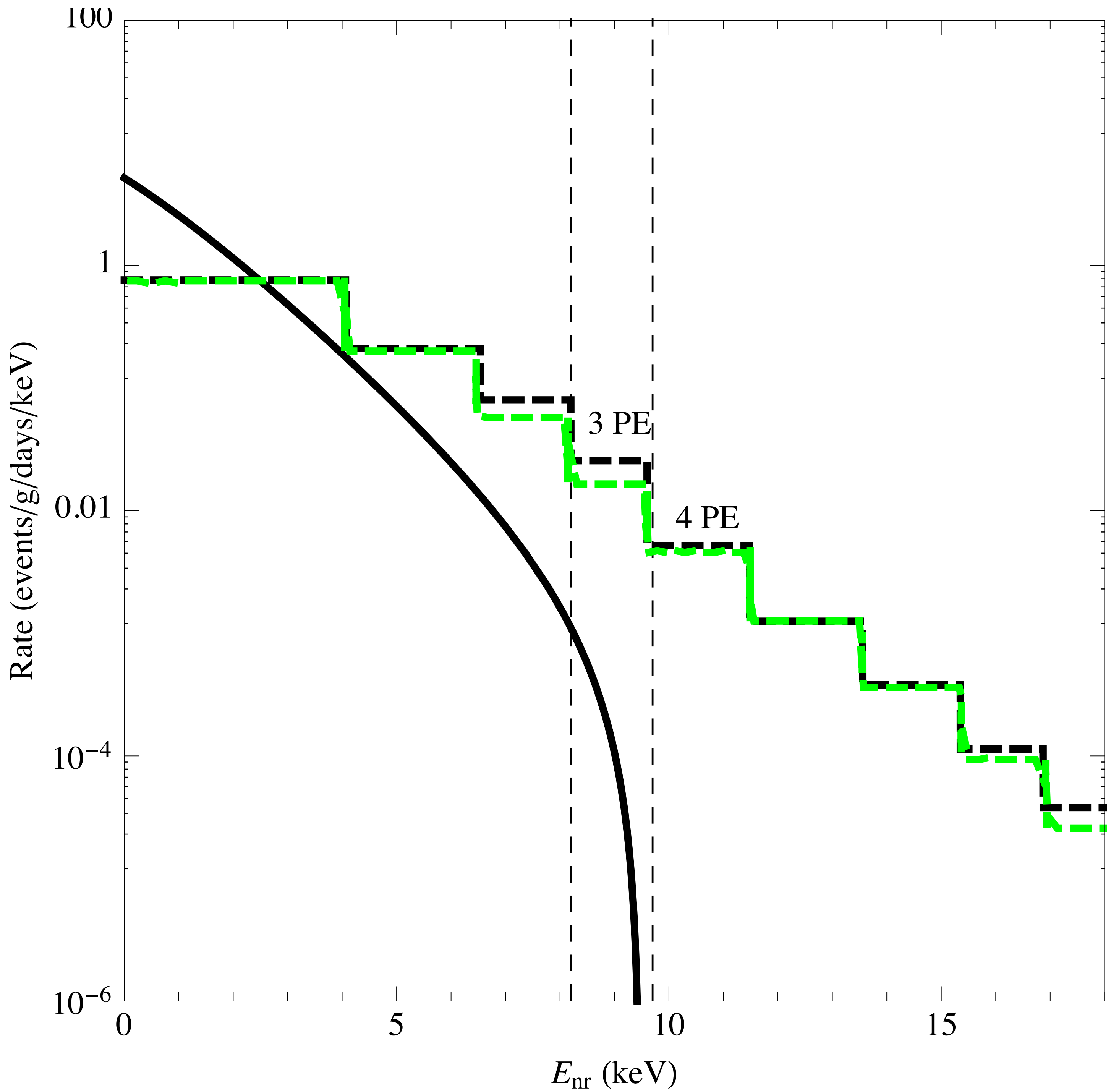


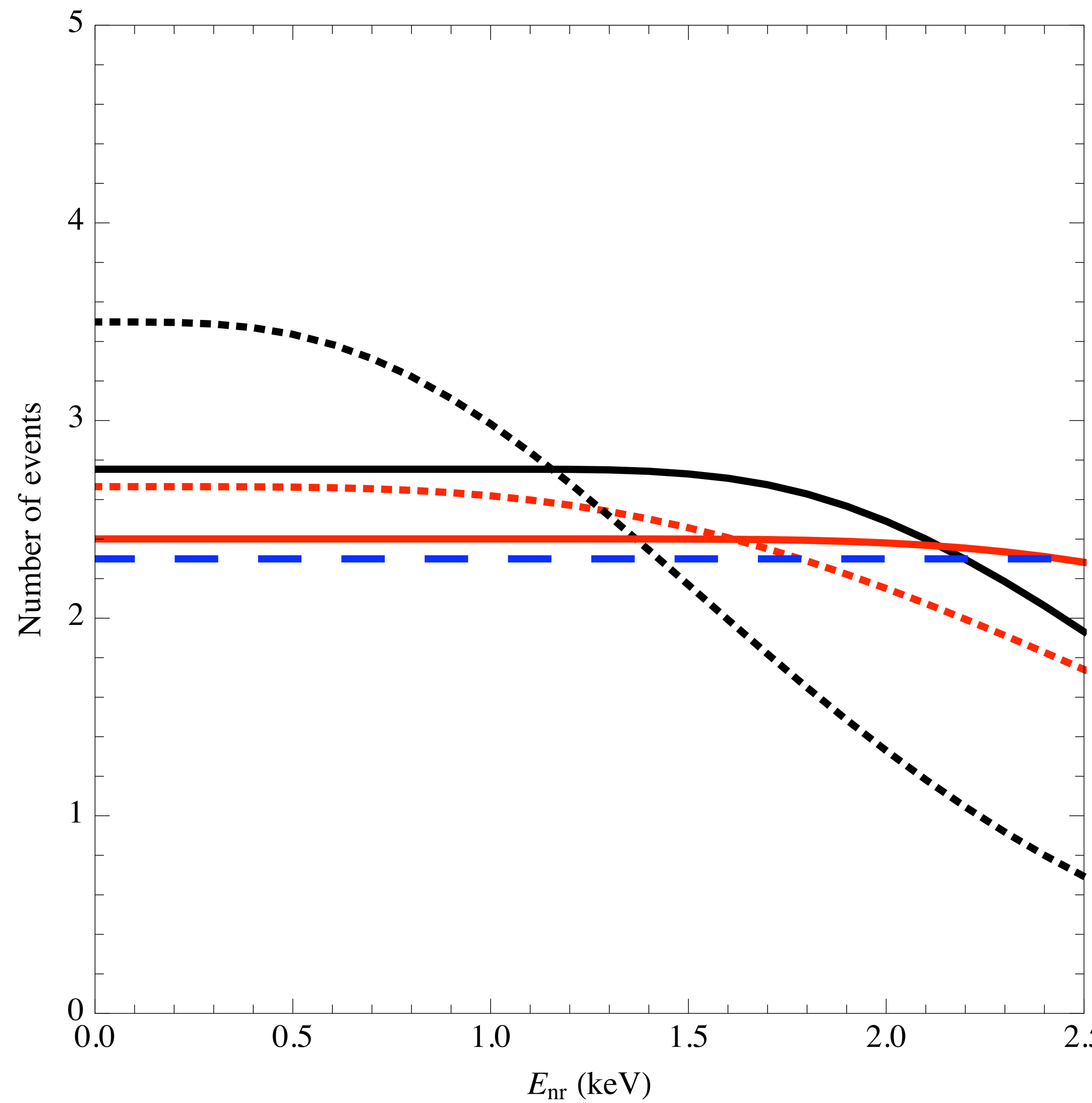
- similar constraints considering the difference in the BR
- Z-like less constraint because the kinetic temperature is ~ few MeV and $M_{\min} = 10^{-6} M_{\odot}$, while for the scalar singlet the kinetic decoupling arises at the same time than the freeze-out

Xenon100: discussion on Leff

C.A. and M.Tytgat, arXiv:1007.2765

Poisson fluctuation in the PE counting



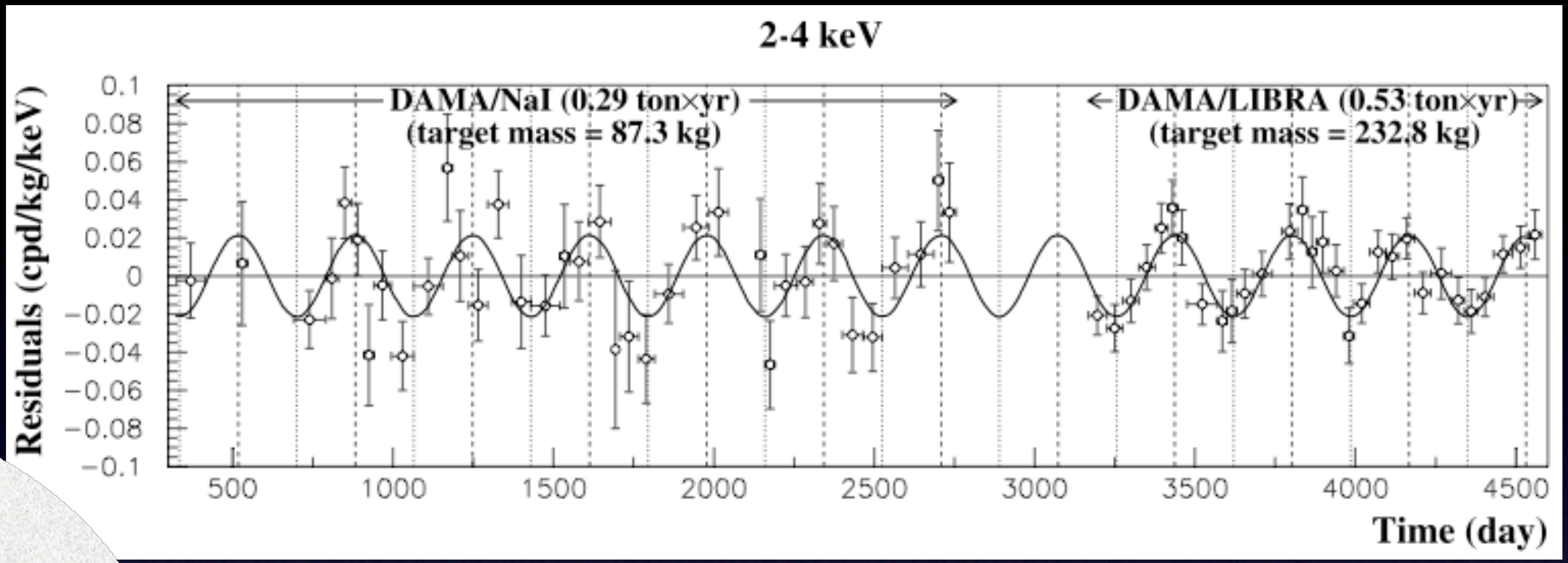


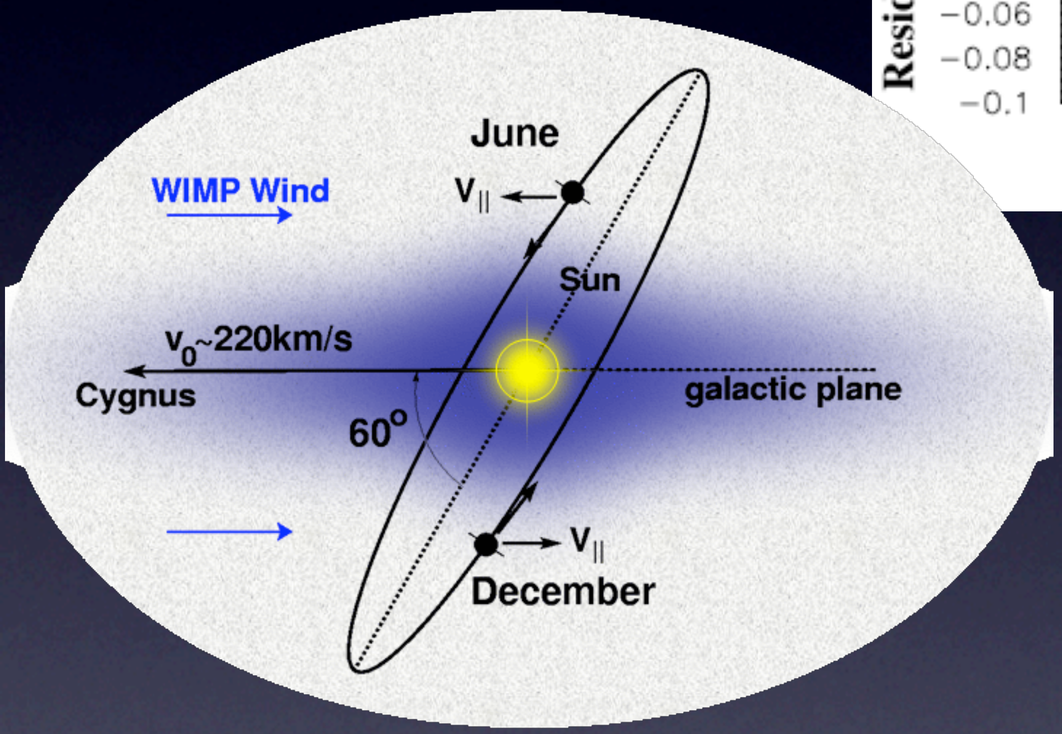
Effect of the threshold value on the exclusion limits

DAMA/LIBRA

Dama coll., Eur.Phys.J.C56:333-355,2008 (arXiv:0804.2741)

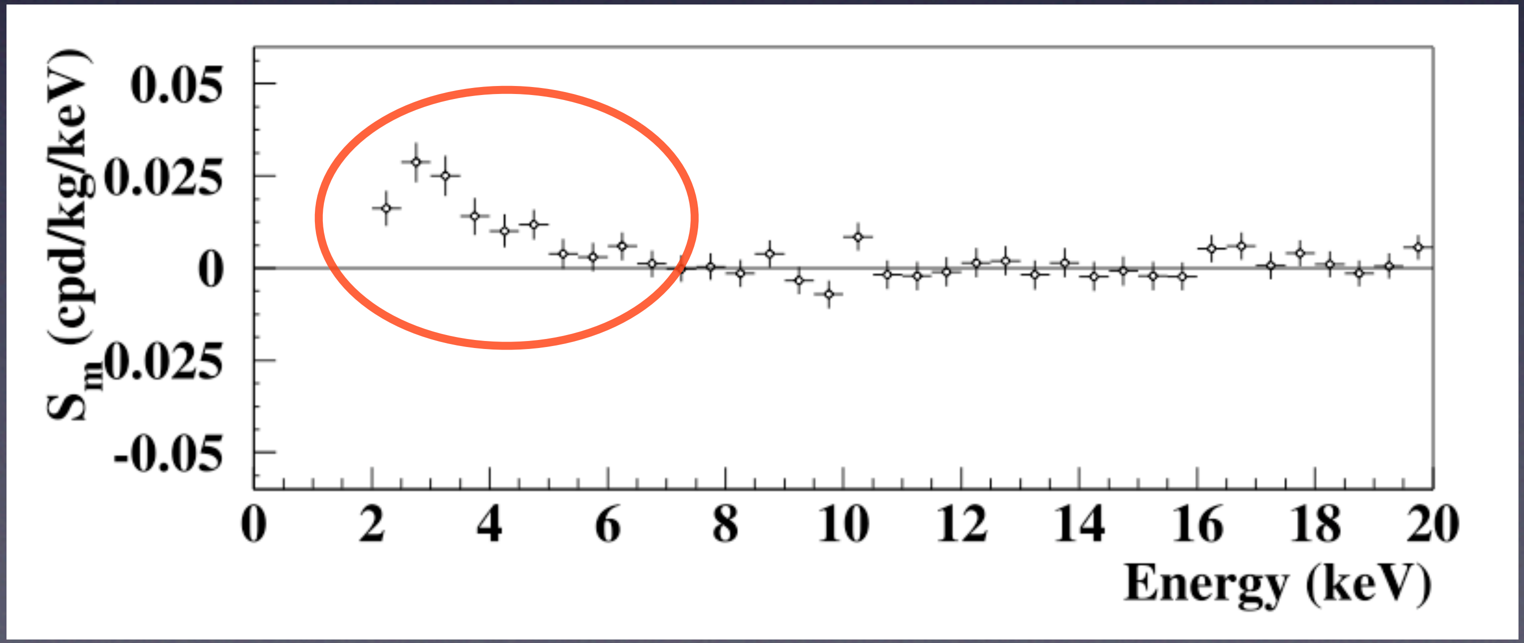
Scintillator + annual modulation signature





$$S_m = \left.\frac{dR}{dE_R}\right|_{mod} \simeq \frac{1}{2}\left\{\frac{dR}{dE_R}(\text{June } 2) - \frac{dR}{dE_R}(\text{December } 2)\right\}$$

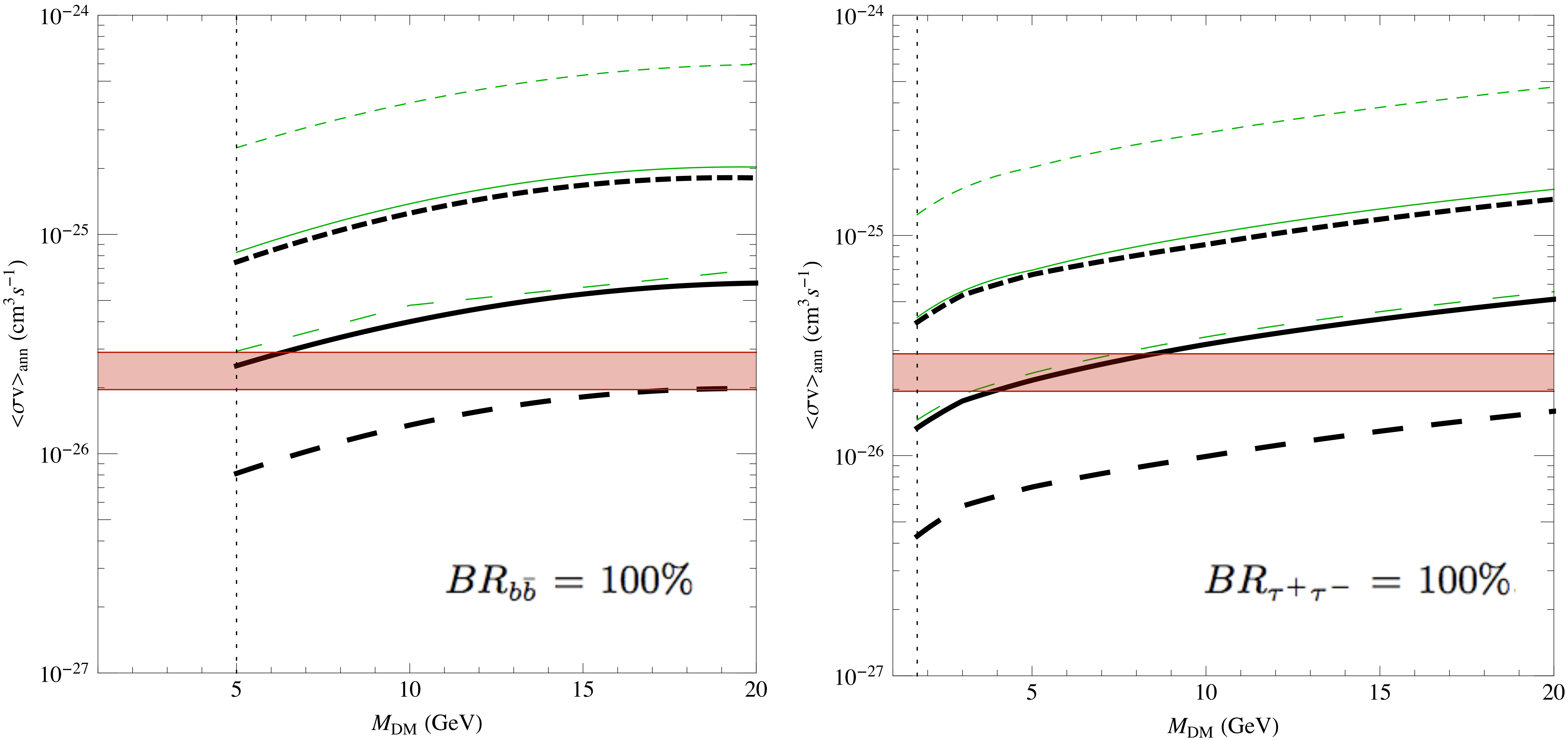
Signal at $8.2\ \sigma$ C.L.



Total exposure: 0.82 ton x year
11 annual cycles

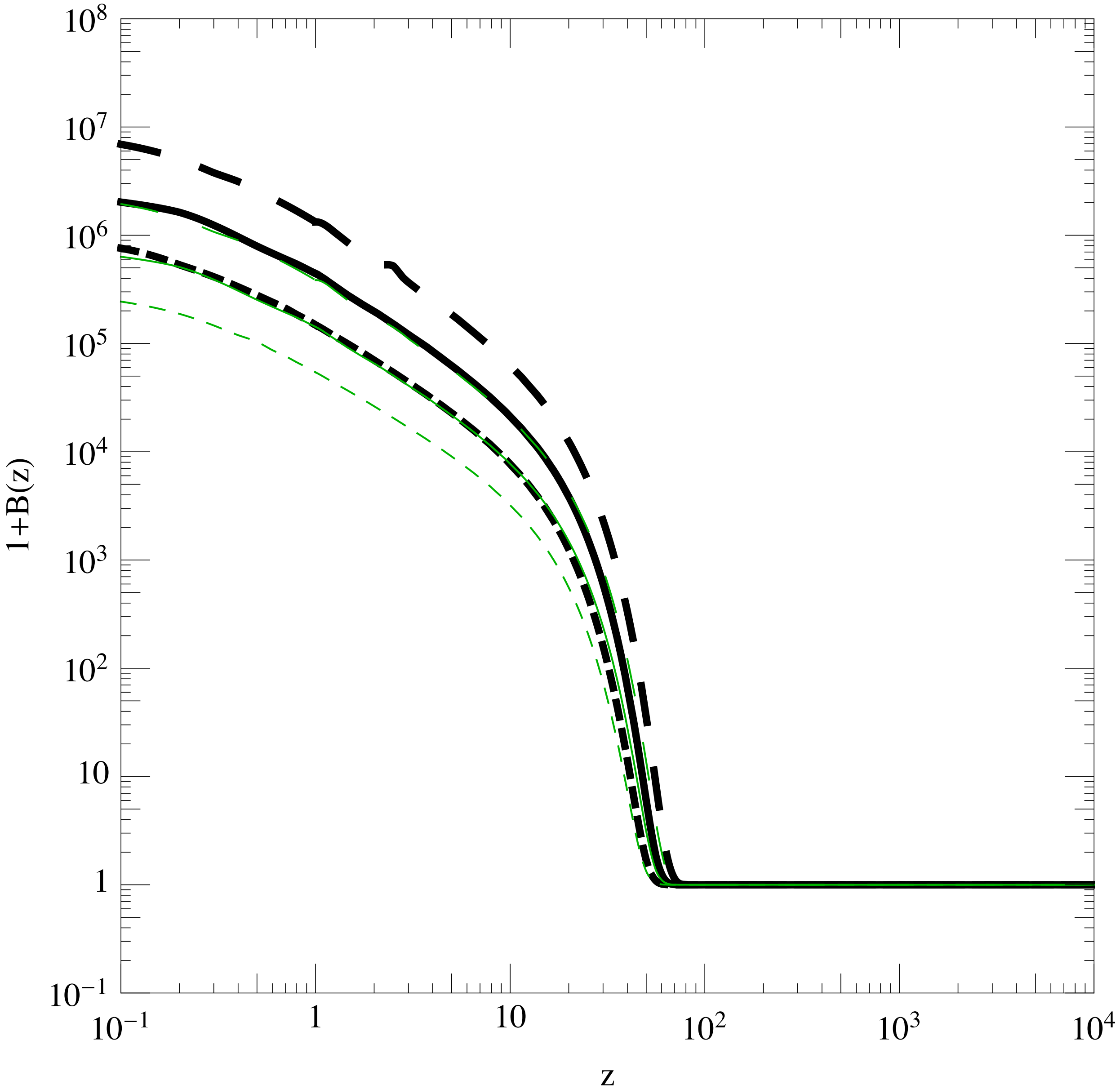
Model independent upper bounds for light WIMPs

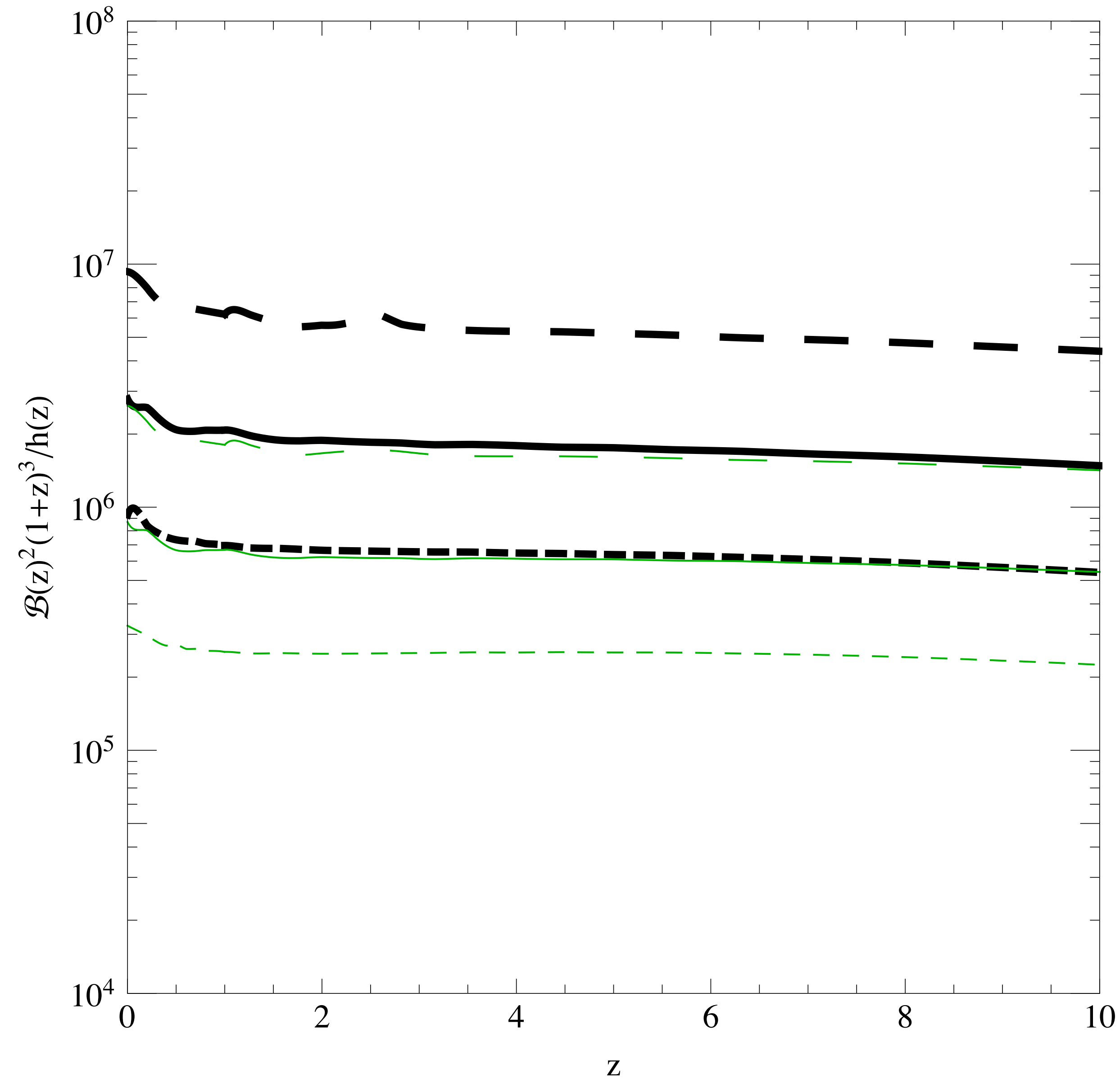
C.A. and M.Tytgat, arXiv:1007.2765



Dark Matter density profile as a function of z

C.A. and M.Tytgat, arXiv:1007.2765





$$F_{\rm NFW}(c_{vir}) = \frac{c_{vir}^3}{3}\left(1 - \frac{1}{(1+c_{cvir})^3}\right)\left(\mathrm{Log}(1+c_{vir}) - \frac{c_{vir}}{(1+c_{vir})}\right)^{-2}$$

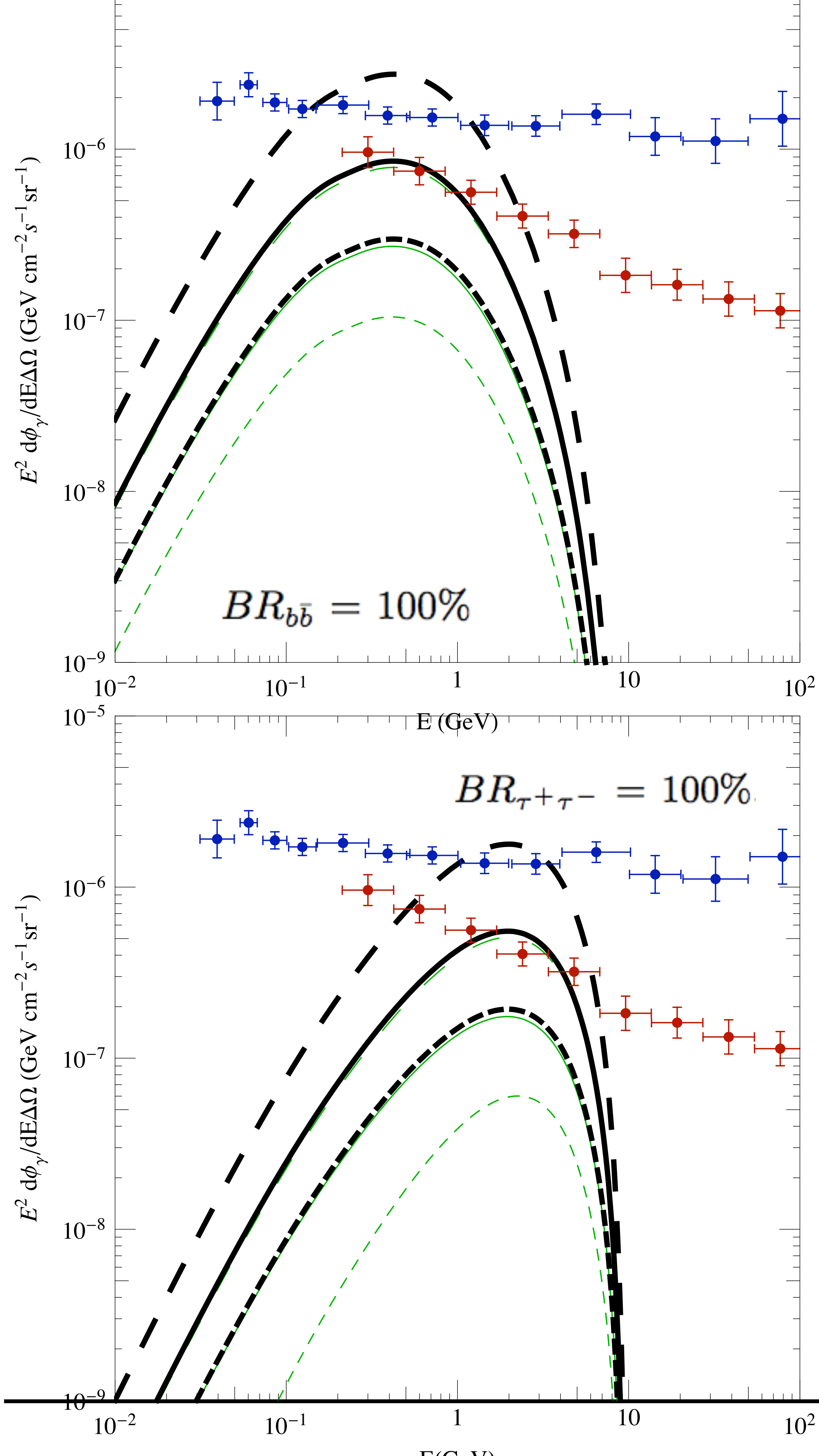
$$M_{\rm min} = 4/3\ \rho_{DM}(\pi/k_{\rm fs})^3\, M_\odot$$

$$c_{vir}(z, M) = \frac{c_{vir}(0, M)}{1+z}$$

$$M_{\rm min} \approx 2.9 \times 10^{-6} \left(\frac{1 + \ln(g_{\rm eff}^{1/4} T_{\rm kd}/50\,\mathrm{MeV})/19.1}{(M_{\rm DM}/100\,\mathrm{GeV})^{1/2} g_{\rm eff}^{1/4} (T_{\rm kd}/50\,\mathrm{MeV})^{1/2}} \right) M_\odot$$

T. Bringmann arXiv:0903.0189

U. A.Green, S. Hoffman and D. Schwartz astro-ph/0503387

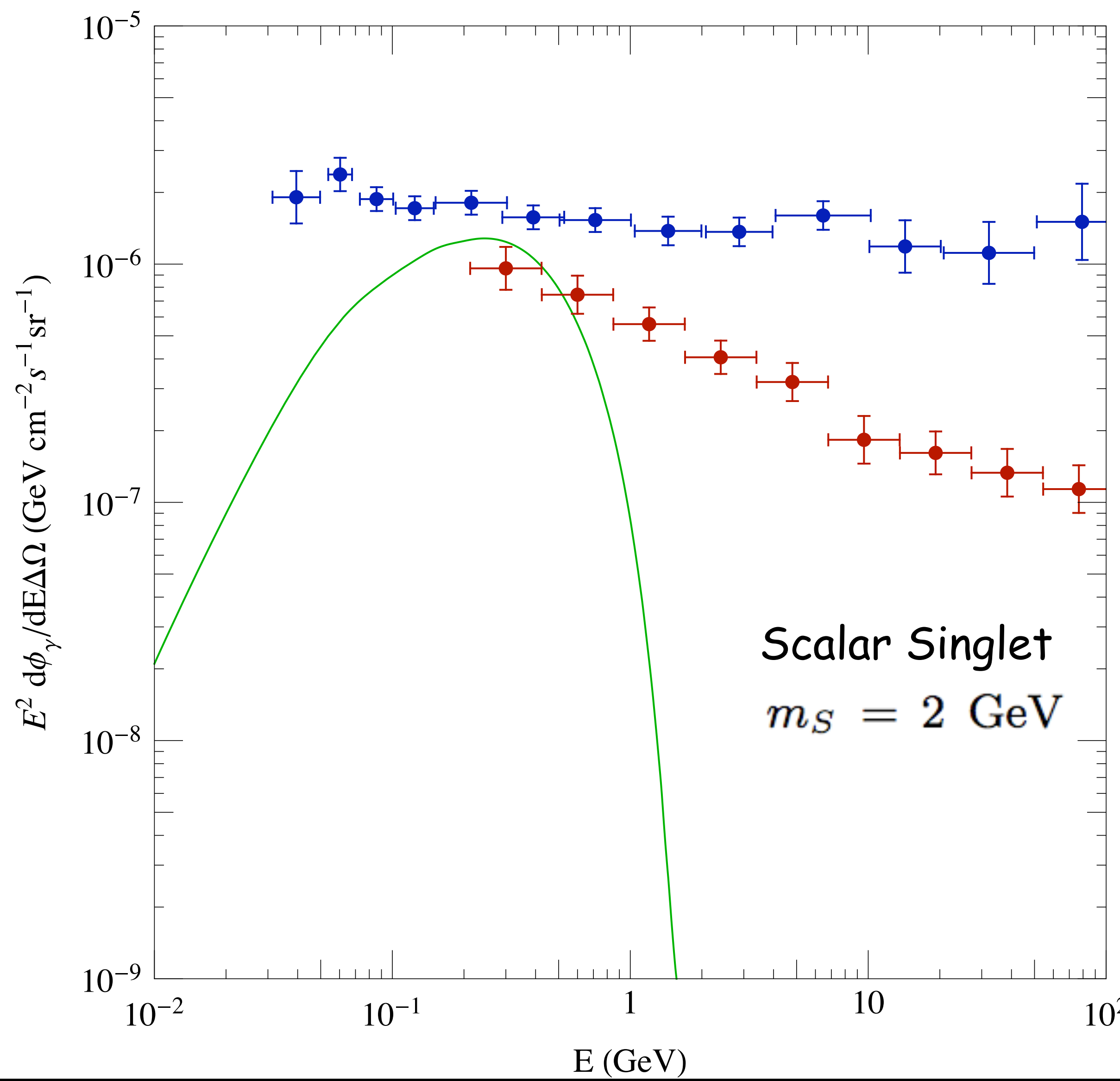


Gamma-ray flux

C.A. and M.Tytgat, arXiv:1007.2765

IGRB Fermi-LAT data
A.Abdo et al. PRL104 (2010), arXiv:1002.3603

IGRB Egret data
A.Strong, I.Moskalenko and O.Reimer, Astrophys.J.613 (2004), astro-ph/0405441



Optical depth

C.A. and M.Tytgat, arXiv:1007.2765

$$\begin{aligned} \text{Photo-ionization} \quad & \gamma + H(He, He^+) \rightarrow e^- + H^+(He^+, He^{++}), \\ \text{Compton Scattering} \quad & \gamma + e^- \rightarrow \gamma + e^-, \\ e^+e^- \text{pair production on matter} \quad & \gamma + A \rightarrow A + e^+ + e^-, \\ \text{Photon-photon scattering} \quad & \gamma + \gamma_{\rm BkGrd} \rightarrow \gamma + \gamma, \\ e^+e^- \text{pair production} \quad & \gamma + \gamma_{\rm BkGrd} \rightarrow e^+ + e^-. \end{aligned}$$

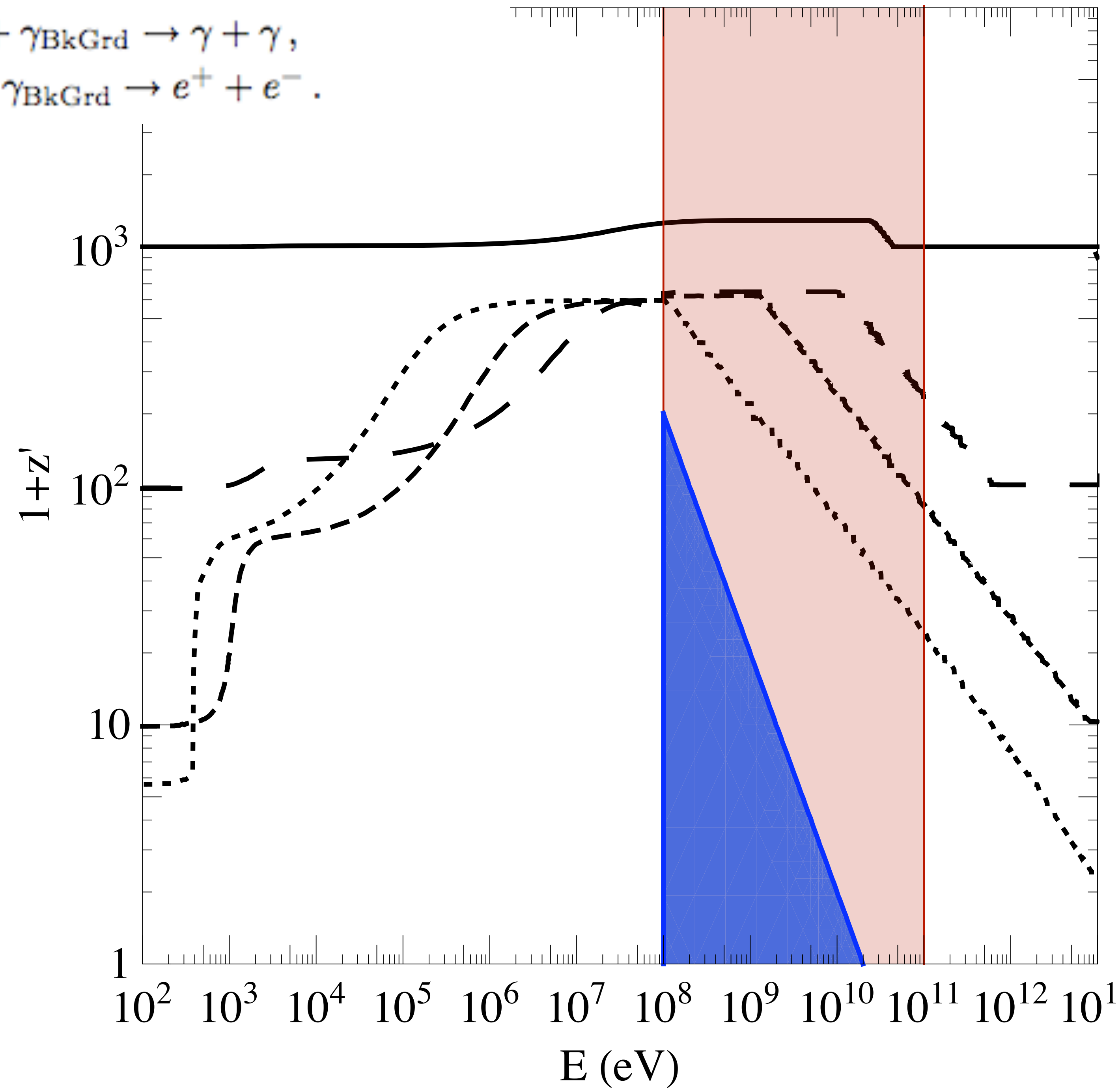
$\tau(E', z, z') = 1$

$z = 1000$

$z = 10$

$z = 0$

$z = 100$



allowed redshifts at emission in function of energy for a candidate with mass < 20 GeV

Fermi-LAT energy range

Dwarf Spheroidal Galaxies (dSphs)

Fermi-LAT collaboration: A.A. Abdo et al.
Astrophys.J 712 (2010), arXiv:1001.4531

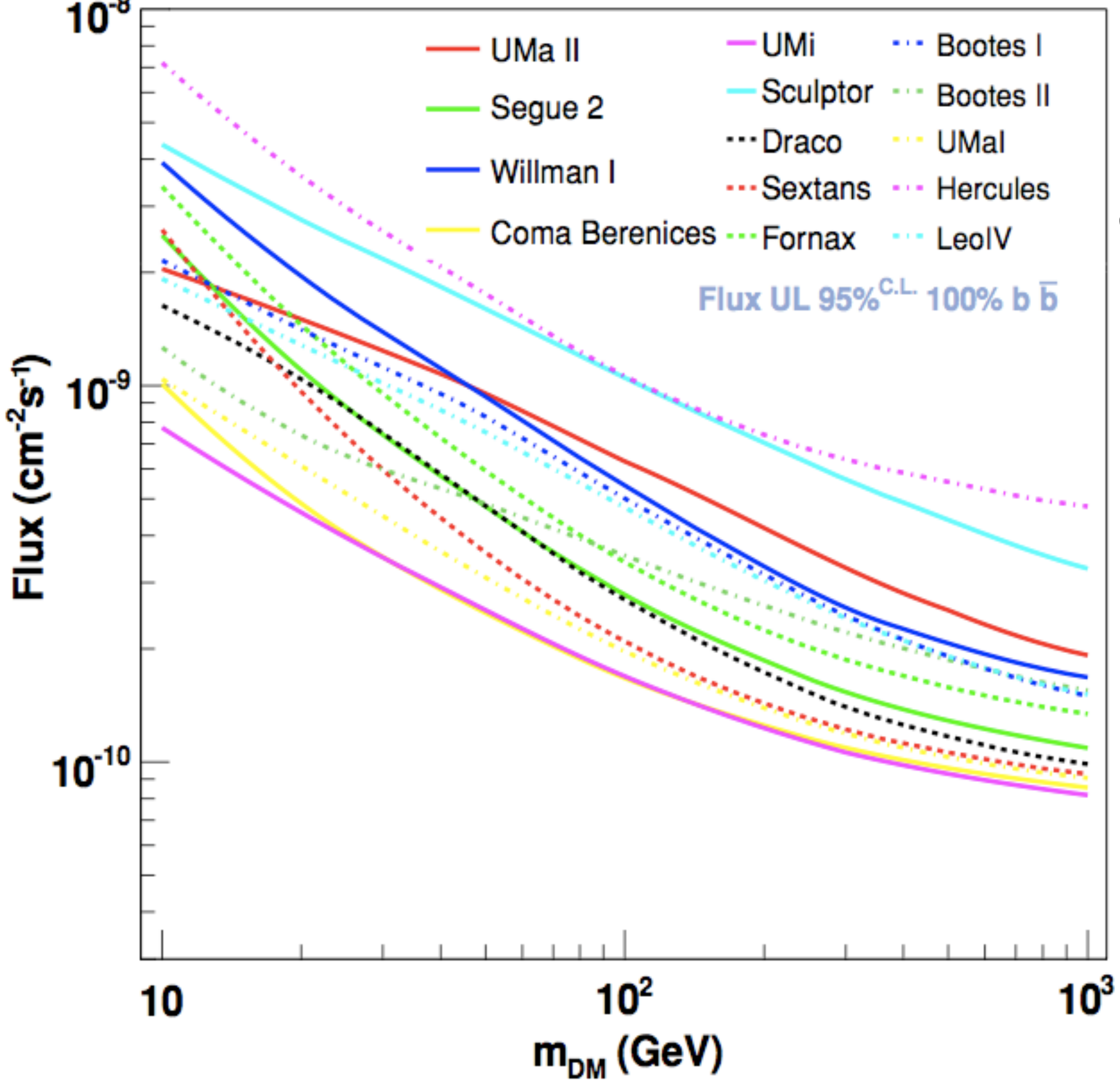
$$\Phi^{\rm cosmo} = J(\psi)$$

$$\rho(r) = \begin{cases} \frac{\rho_s r_s^3}{r(r_s+r)^2} & \text{for} \quad r < r_t \\ 0 & \text{for} \quad r \geqslant r_t \end{cases}$$

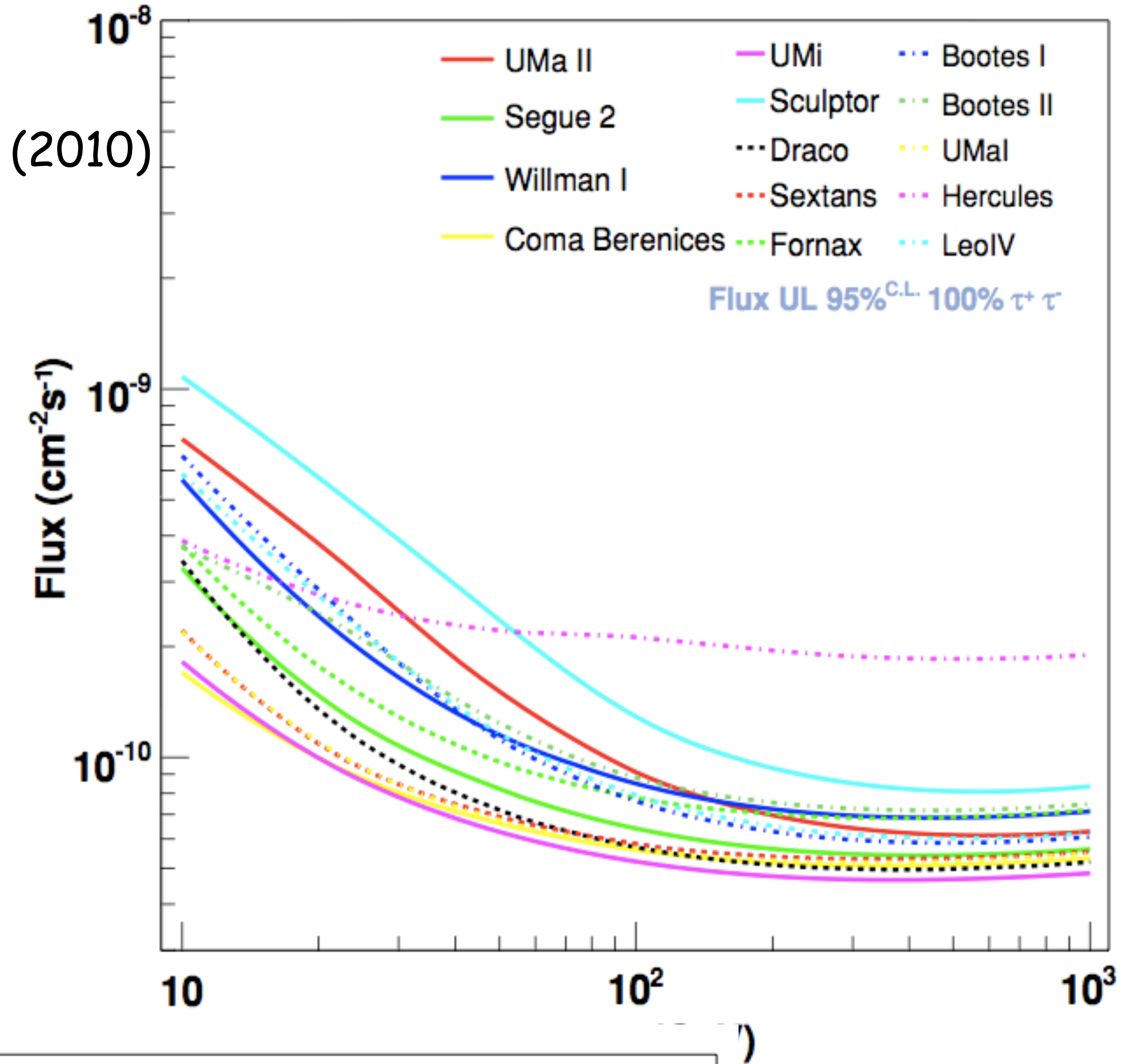
$$J(\psi) = \int_{\rm l.o.s} dl(\psi)\rho^2(l(\psi))$$

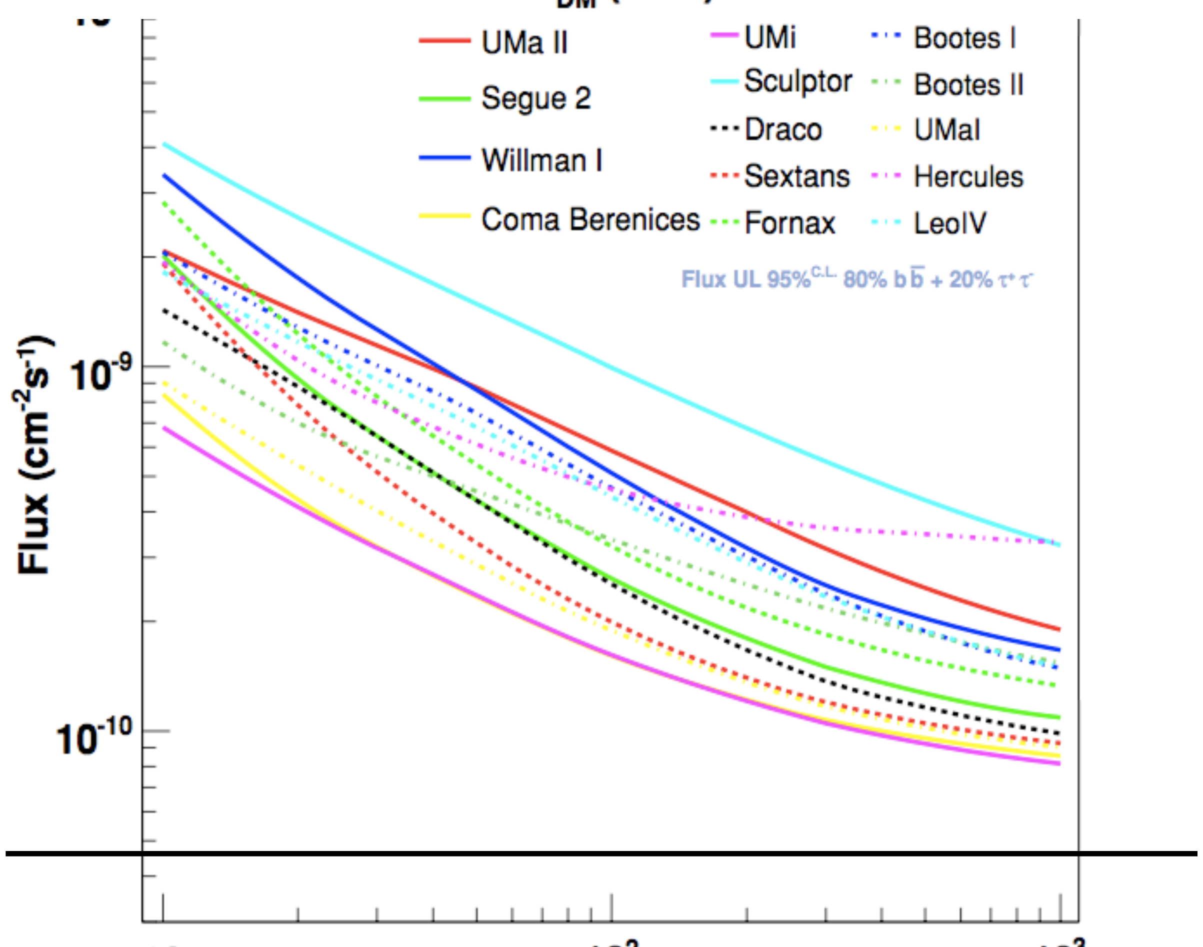
Name	$[\langle R\rangle, \langle P\rangle]$	$[\langle R^2\rangle - \langle R\rangle^2, \langle P^2\rangle - \langle P\rangle^2, \langle RP\rangle - \langle R\rangle\langle P\rangle]$ $R \equiv \log_{10}(r_s/\mathrm{kpc})$, $P \equiv \log_{10}(\rho_s/M_\odot\ \mathrm{kpc}^{-3})$	$J^{\rm NFW}$ $(10^{19}\ \frac{\rm GeV^2}{\rm cm^5})$
Ursa Major II	[−0.78, 8.54]	[0.0417, 0.0986, −0.0554]	$0.58^{+0.91}_{-0.35}$
Coma Berenices	[−0.79, 8.41]	[0.0603, 0.132, −0.0820]	$0.16^{+0.22}_{-0.08}$
Bootes I	[−0.57, 8.31]	[0.0684, 0.165, −0.0931]	$0.16^{+0.35}_{-0.13}$
Usra Minor	[−0.19, 7.99]	[0.0430, 0.116, −0.0697]	$0.64^{+0.25}_{-0.18}$
Sculptor	[−0.021, 7.57]	[0.0357, 0.0798, −0.0528]	$0.24^{+0.06}_{-0.06}$
Draco	[0.32, 7.41]	[0.0236, 0.0364, −0.0286]	$1.20^{+0.31}_{-0.25}$
Sextans	[−0.43, 7.93]	[0.0302, 0.109, −0.0570]	$0.06^{+0.03}_{-0.02}$
Fornax	[−0.24, 7.82]	[0.0474, 0.140, −0.0798]	$0.06^{+0.03}_{-0.03}$

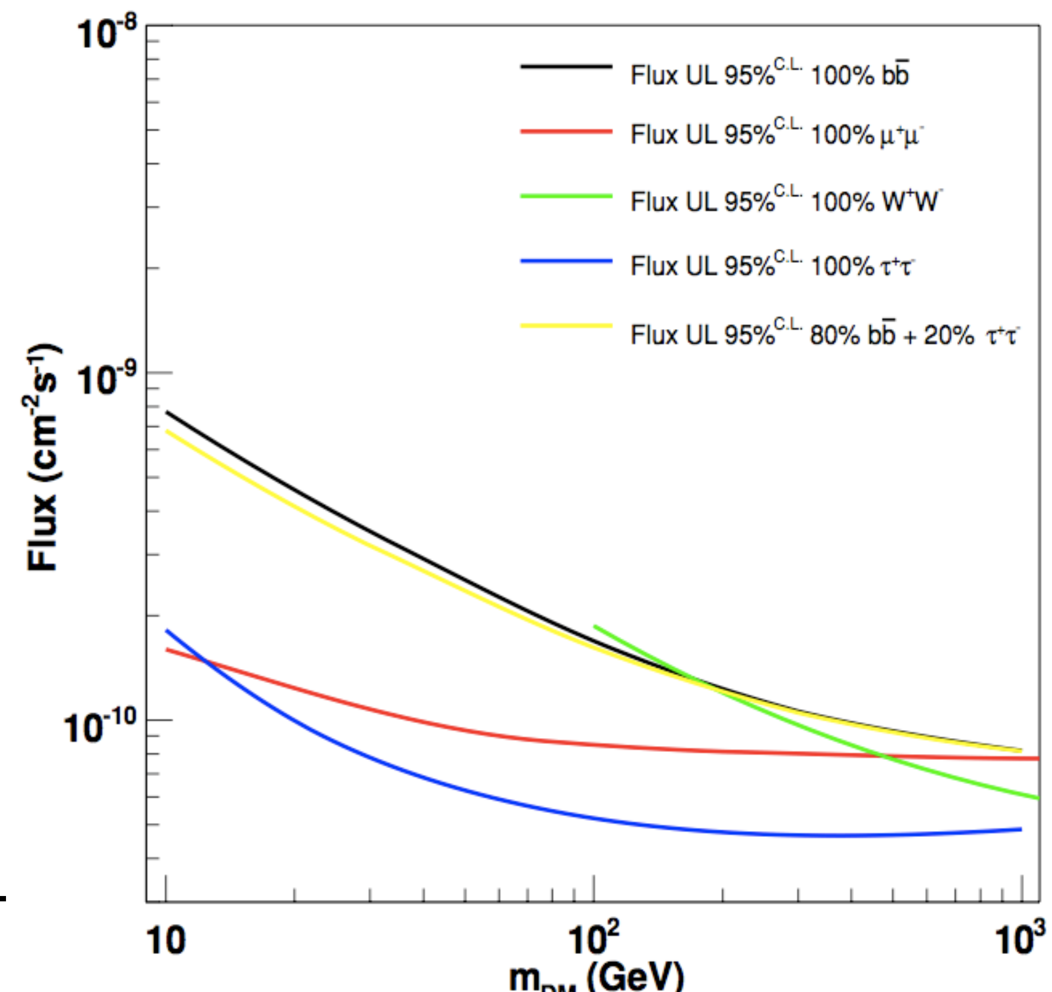
Fermi data at the Galactic Center: hint of a light DM candidate
(D.Hooper and L.Goodenough arXiv:1010.2752)



A.A. Abdo et al.
Astrophys.J 712 (2010)
arXiv:1001.4531







CDMS-II

The event rate R depends on the cross-section DM-nucleon and on the DM mass

CDMS-II run ~ 600 kg-day of Ge

10-100 keV energy range

Significance of the 2 events:

$$1.64\ \sigma$$

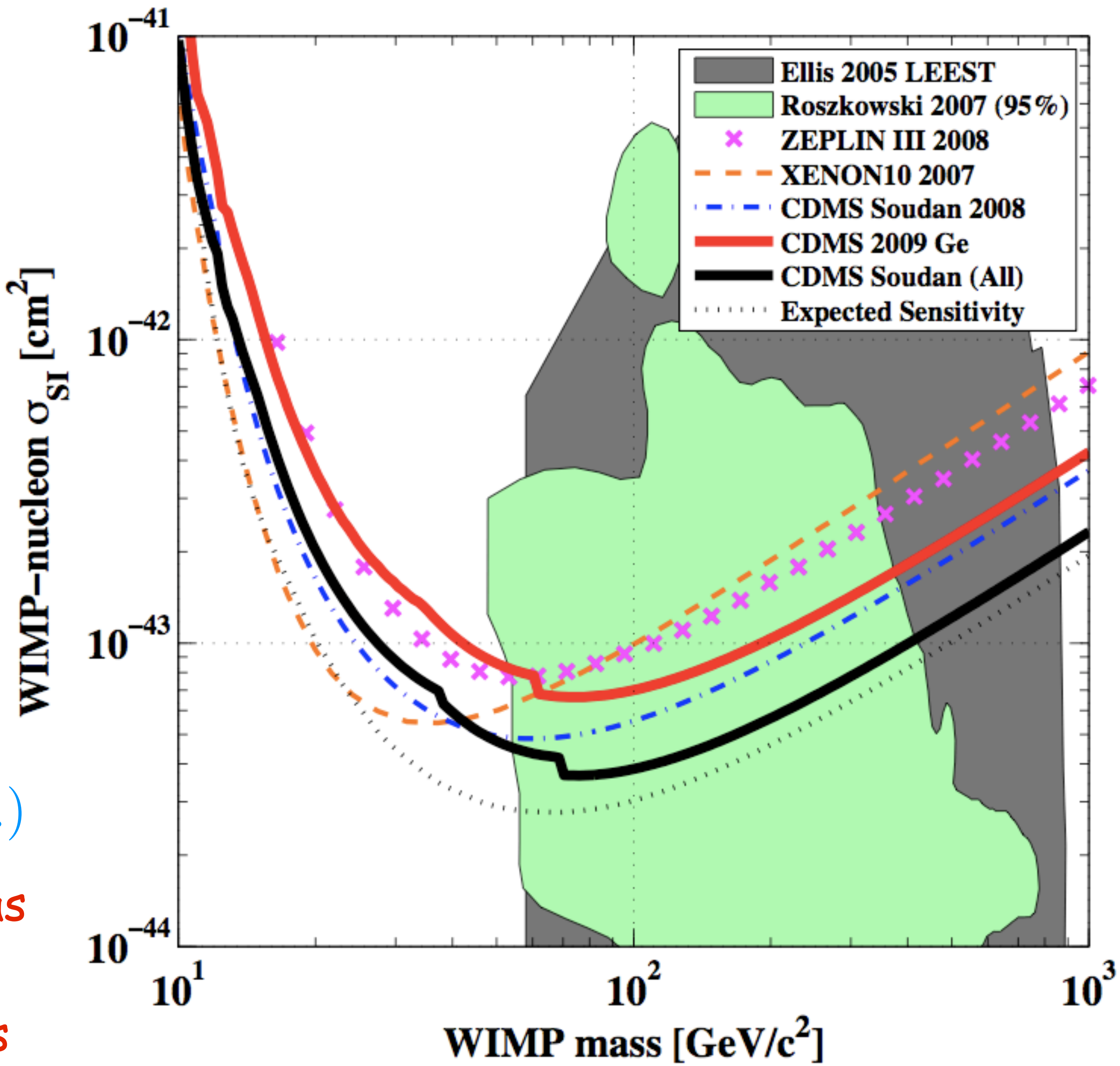
23% of probability that the 2 events are of prosaic origin

Background estimate:

$$0.8\ \pm\ 0.1\ (\mathrm{stat.})\ \pm\ 0.2\ (\mathrm{syst.})$$

2 events cannot be interpreted as significant evidences of WIMP but cannot be rejected as signals

Exclusion limit at 90% C.L.



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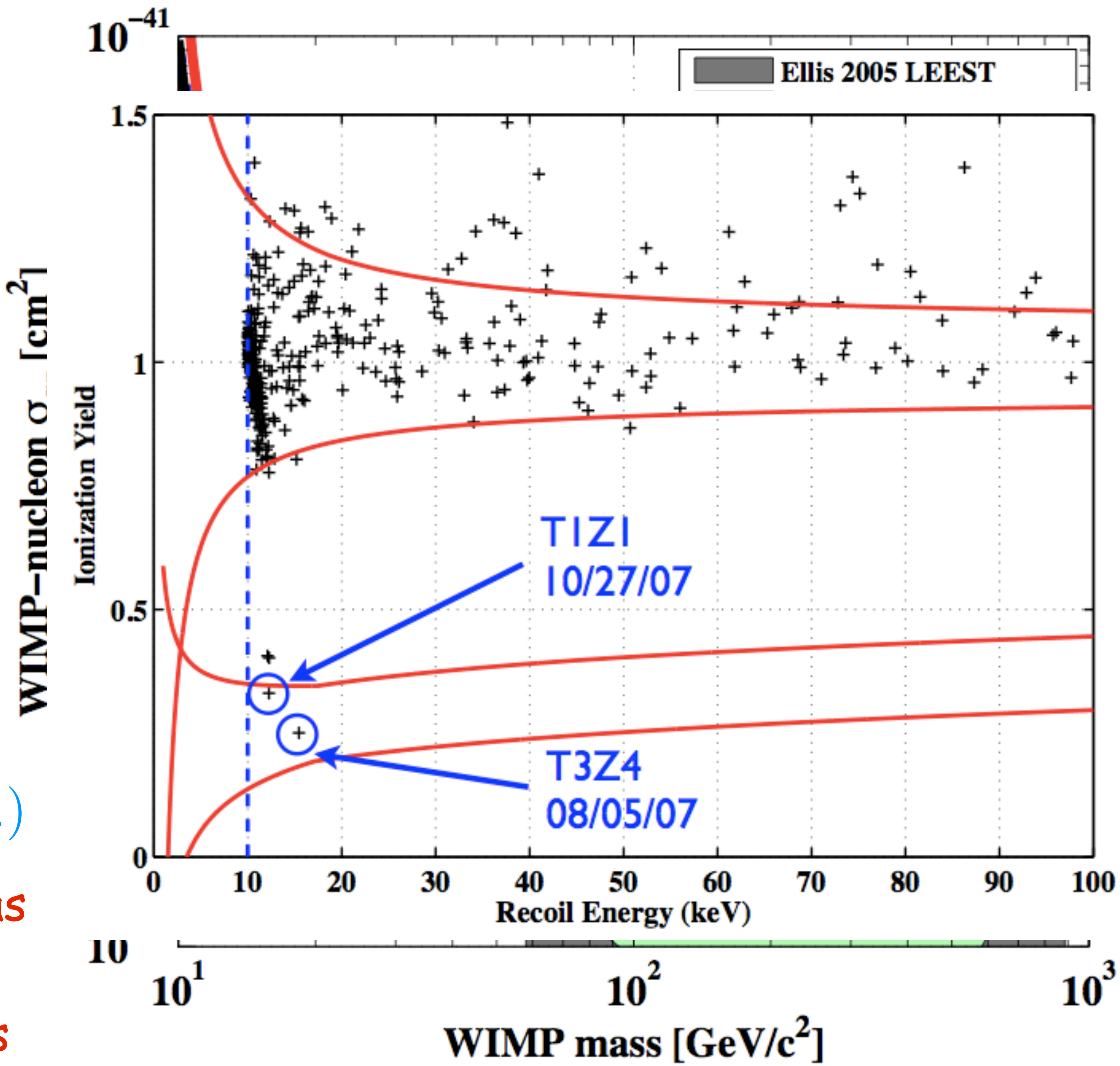

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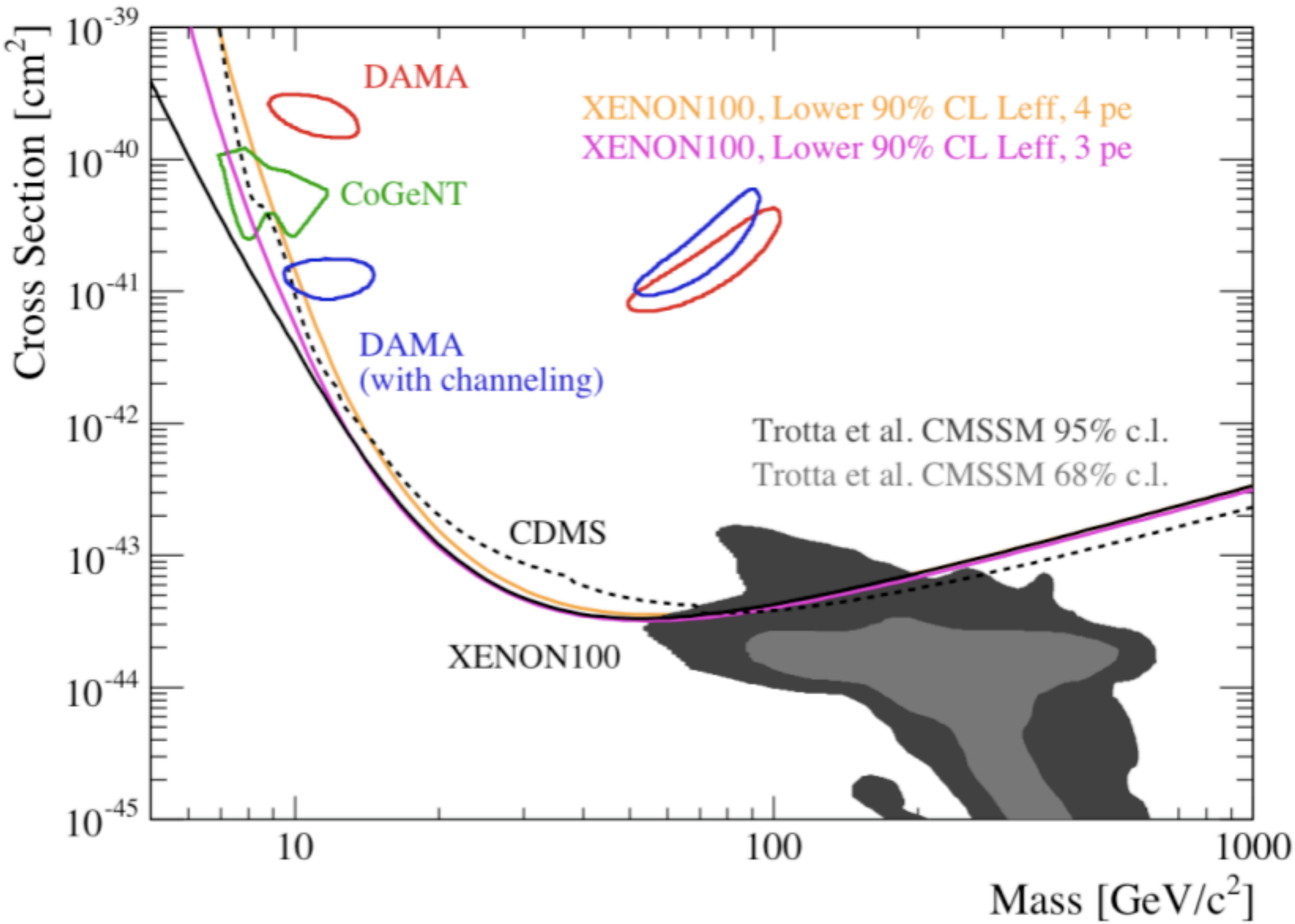
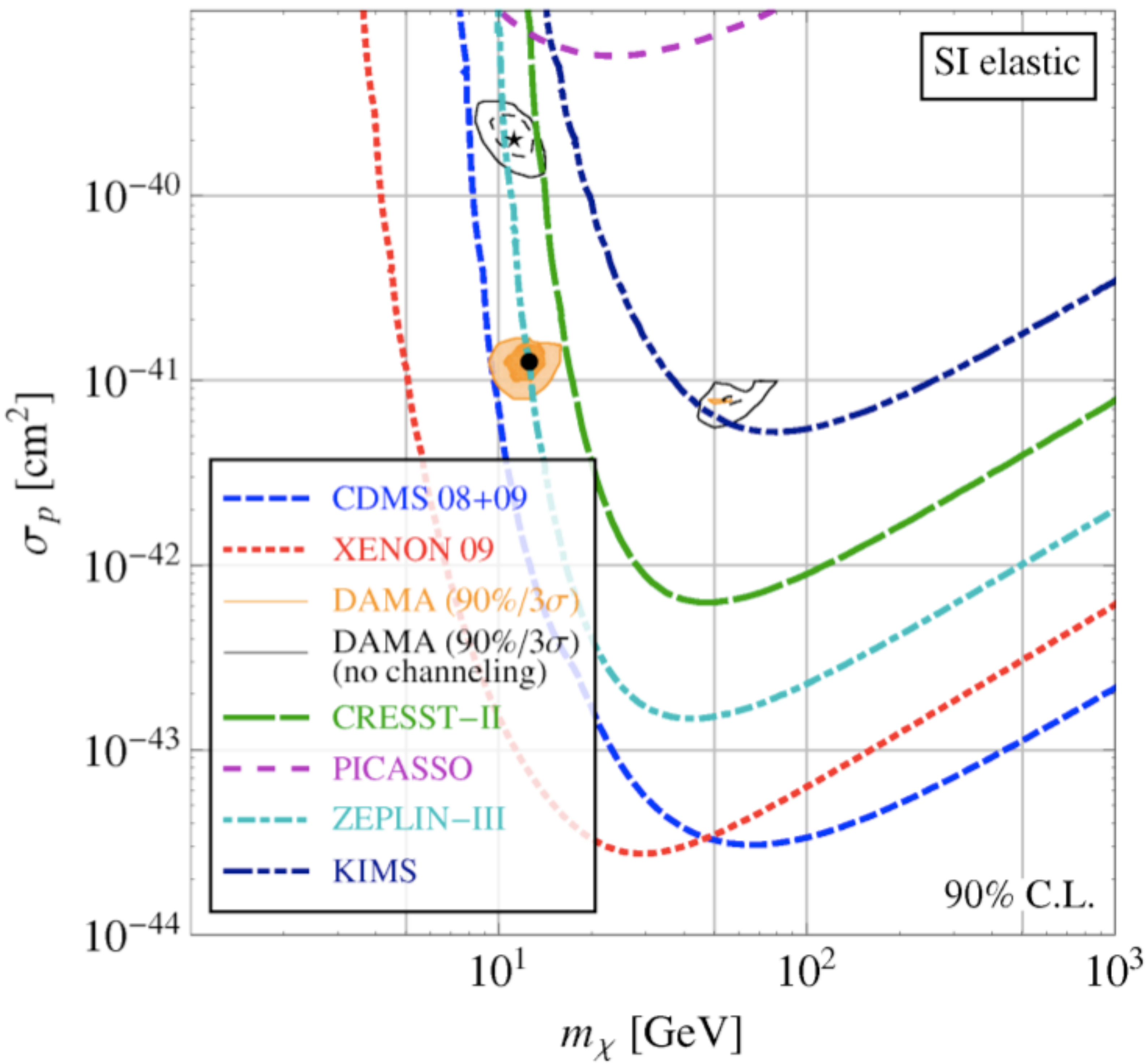
Xenon100

E.Aprile et al., PRL105 (2010), arXiv:1005.0380
E.Aprile et al. arXiv:1005.2615

Exclusion limit at 90% C.L.



Model independent analysis -> Tension in reconcile all the experimental results

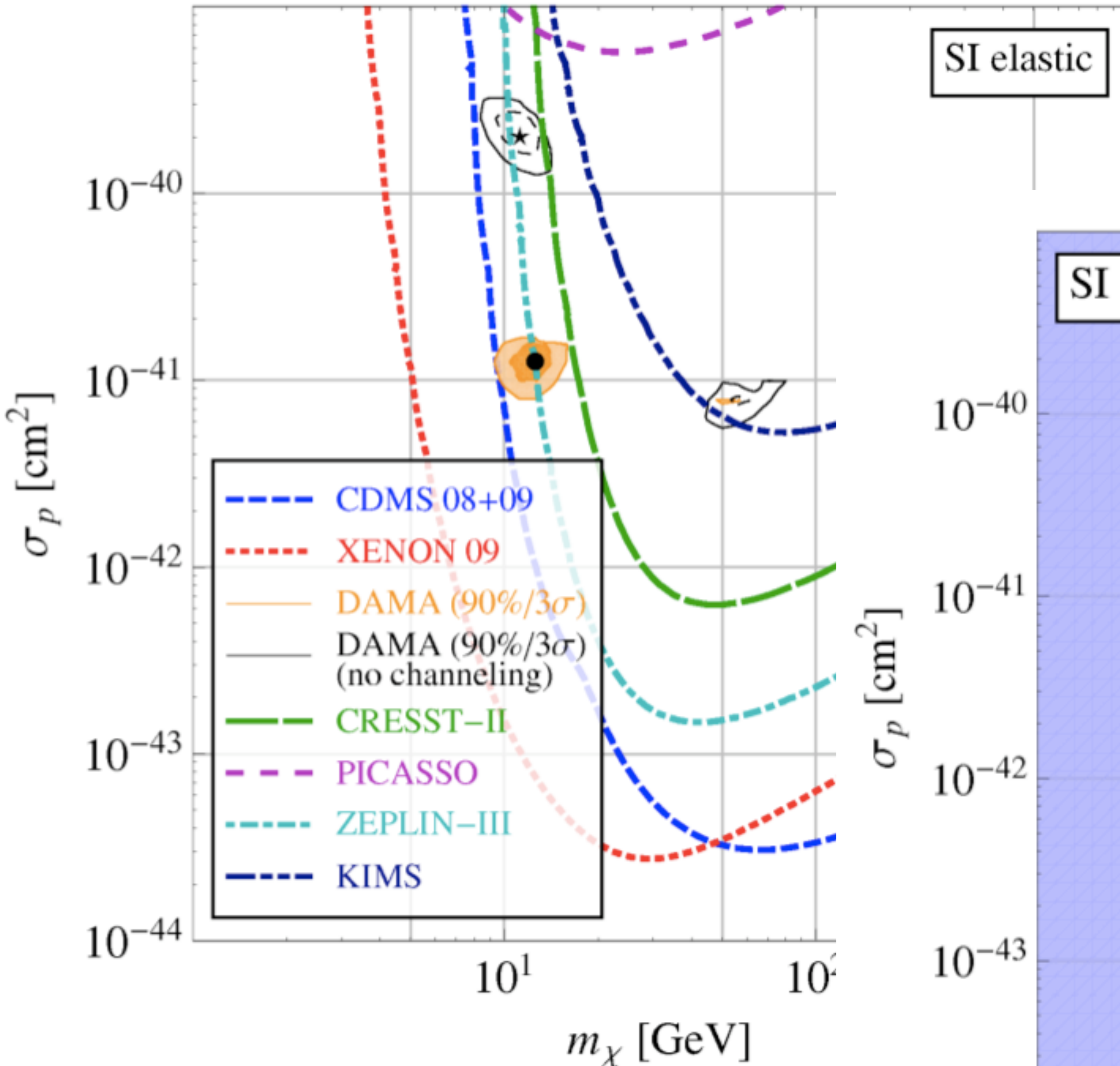


J. Kopp, T. Schwetz and J. Zupan
JCAP 1002:014 (2010), arXiv: 0912.4264

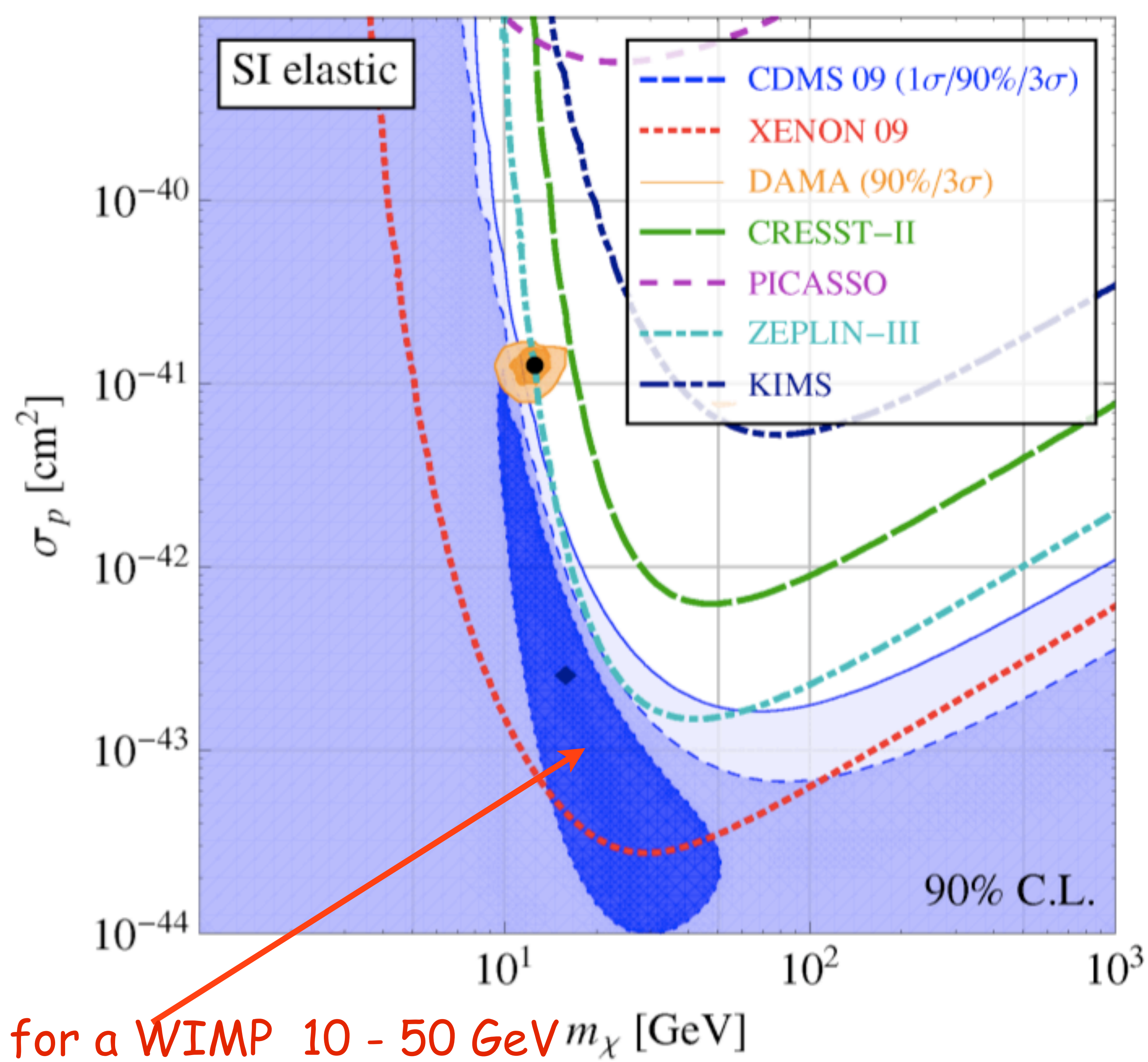
- CDMS-II exclusion limit at 90% C.L.
- Xenon10 bound uncertain

Model independent analysis -> Tension in reconcile all the experimental results

J. Kopp, T. Schwetz and J. Zupan
JCAP 1002:014 (2010), arXiv: 0912.4264



CDMS as signal



- CDMS-II exclusion limit at 90% C.L.
- Xenon10 bound uncertain

preferred low mass range for a WIMP 10 - 50 GeV

Astrophysics

Inverse Averaged velocity distribution

$$\eta(E_R, t) = \int_{v_{min}} d^3\vec{v}\, \frac{f(\vec{v}(t))}{v}$$

$$v_{min} = \sqrt{\frac{1}{2M_N E_R}}\left(\frac{M_N E_R}{\mu} + \delta\right)$$

minimum velocity to scatter @ E_R

δ = 0 elastic scattering

δ = 100 KeV inelastic scattering
required an higher velocity to scatter @ ER
sensitive to tail WIMP distribution

$f(\vec{v}(t))$ assumed isotropic
truncated Maxwellian distribution

v_0 = 220 km/s

450 km/s< v_{esc} < 650 km/s

ρ_{DM} = 0.3 GeV/cm^3 local density at the sun position

Velocity distribution

Basic assumptions: different halo models and/or velocity values analyzed eg.
Belli '02, March-Russell '08, Savage '09 and more...

$$\eta(E_R, t) = \int_{v_{min}} \mathrm{d}^3\vec{\mathrm{v}}\, \frac{\mathrm{f}(\vec{\mathrm{v}}(t))}{\mathrm{v}}$$

If the velocity distribution in the galactic frame is isotropic:

$$\eta = \frac{2\pi}{\mathrm{v_E}}(v_+ - v_-)\mathrm{F}(v_{esc}) - \frac{2\pi}{\mathrm{v_E}}\int_{v_-}^{v_+} \mathrm{F(v)\,dv}$$

with:

$$v_\pm = \min\{v_{esc}, v_{min} \pm v_\oplus\}$$

$$\mathrm{F}(v) = \int v\, \mathrm{f_{gal}}(v)\, dv$$

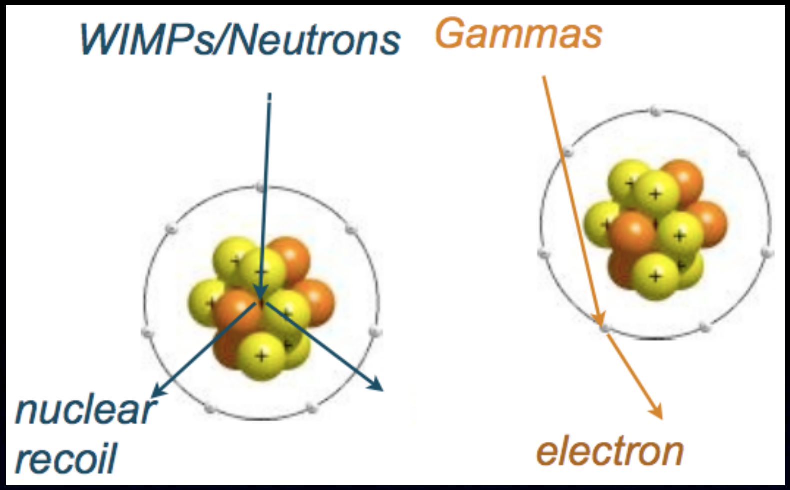
v_{esc} = escape velocity

v_{min} = minimum WIMP velocity to scatter

$v_\oplus$ = Earth velocity in the galactic frame

$$v_\oplus(t) = v_\odot + v_{\mathrm{EO}}(t)$$

Backgrounds

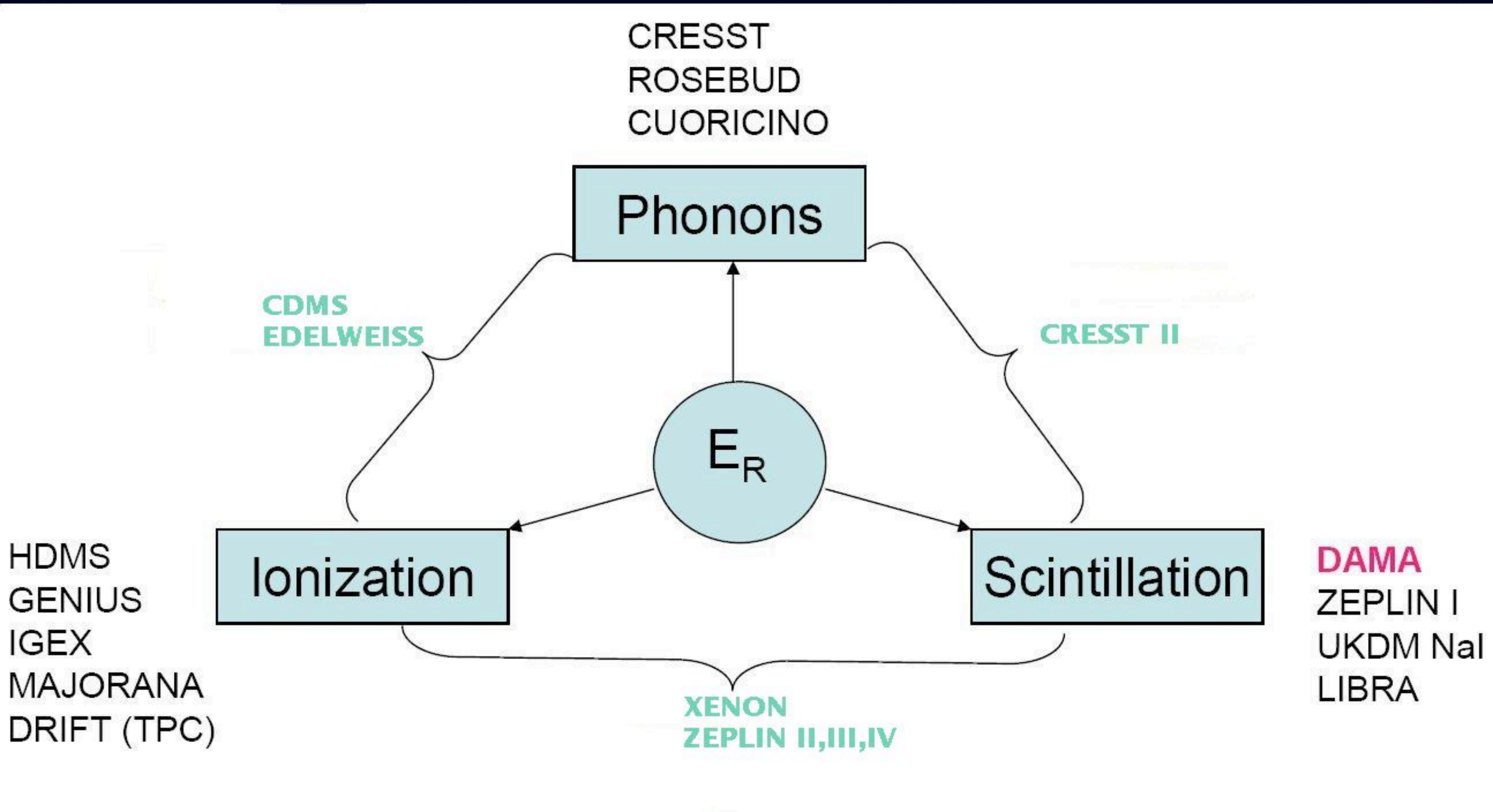


Background: neutron, gamma, electron, radioactivity

Underground detectors

Background rejection techniques

- phonon
- scintillation
- ionization



Typically a detector measures two quantities to disentangle WIMP nuclear recoils from the background or relates on a WIMP signature